Distribution and Relative Sensitivity to Acidification of Soils Sand River Area, Alberta

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DISTRIBUTION AND RELATIVE SENSITIVITY TO ACIDIFICATION OF SOILS SAND RIVER AREA, ALBERTA

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DISTRIBUTION AND RELATIVE SENSITIVITY TO ACIDIFICATION OF SOILS SAND RIVER AREA, ALBERTA

by

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for

Research Management Division
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and
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PREFACE

It should be emphasized that this report represents the results of an initial attempt in Alberta to classify the soils of an area into categories of sensitivity on the basis of deductive interpretations of data and other information that are acquired during the conduct of a soil survey. The sensitivity classification criteria and scheme that were developed were designed primarily for sensitivity classification of soils in the Sand River area and will be tested by application. The criteria and scheme of classification should not be considered at this time as a comprehensive system of sensitivity classification of soils in other kinds of regions.

EXECUTIVE SUMMARY

There is increasing apprehension concerning the effects of acidity-generating industrial emissions on terrestrial and other ecosystems. In the case of the terrestrial ecosystem the acidification of soils has received considerable attention. Concomitantly there is much concern about the acidification of soils by the rapidly expanding use of acidifying fertilizers. It has been postulated that both of these anthropogenic sources will cause serious degradation of the soil resources in the future.

Practically all of the airborne anthropogenic sulphur materials in Alberta originate from local sources. The more recent reports indicate that between 275 000 and 300 000 t of sulphur, mostly as SO_2, are emitted annually by industrial establishments. Natural sources of such sulphur amount to about 33 000 t. The rainfall in areas affected by emissions has ranged from 4.5 to 6.0 in pH while in the unaffected locations the pH is commonly between 6.0 and 7.0. Some of the studies on the acidifying effects of the airborne depositions have given variable results but other investigations have shown a decrease of one-tenth to two-tenths pH units in a year. There has been a rapid increase in the use of nitrogen fertilizer in the province, from 60 000 t in 1970 to 250 000 t in 1980. A number of studies have indicated marked reductions in soil pH due to acidity generated by nitrification of the ammonium component in the fertilizers.

To appraise the effects of anthropogenic acidity on soils it would be helpful to understand the nature and magnitude of effects due to acidification from natural causes that were an integral part of the soil forming processes. Dissolved atmospheric and soil CO_2, decomposition and mineralization of organic matter, oxidation of sulphides and ferrous ions, and leaching may contribute to natural acidification. Conversely, the presence of carbonates such as $CaCO_3$ in the soil counterbalances acidification, while deposition

of entrained airborne dust and salts tends to retard it. Likewise inflow or upward movement of mineral charged water into the soil will ameliorate acidification.

Vegetation is also a significant factor. Plant species that take up large amounts of bases in the biological cycle counteract the effects of leaching and favour production of less acidifying organic matter. The net effect of natural acidification is reflected in the range of soils found in the study area. Some are neutral and others are medium acid, undoubtedly due to some differences in soil forming factors. More should be known about how these factors influence the effects of anthropogenic acidity on soils in their natural habitat.

The more evident changes that occur in a soil in response to inputs of acidity are a decrease in pH, an increase in total acidity and a decrease in base saturation. There are several soil acidity parameters of which total acidity and degree of acidity are especially pertinent. The titratable acidity is referred to as total acidity. Total acidity dissociates to a small extent, the dissociation producing hydrogen ions whose concentration, expressed as pH, determines the degree of acidity. A decrease in soil pH generally has deleterious effects on a number of chemical and biochemical processes and thus adversely affects the soil as a medium for plant growth.

The soils differ in the degree of change they undergo in response to a given input of acidity due to differences in their capacity to mollify or otherwise accommodate the effects of acidification. This capacity of a soil is referred to as its sensitivity, that is, the greater the capacity the less sensitive is the soil to acidification effects. As used in this report, soil sensitivity is defined as the relative magnitude of the susceptibility of a soil to degrees of change in its pH, base saturation and mobilization of exchangeable bases (Ca, Mg, K, Na) in response to a given input of acidity. The level of sensitivity of a soil reflects

the integrated result of several factors of which the buffering capacity (BFC) and pH are the most significant. In addition, other soil properties or attributes influence the degree to which the soil responds to acidity inputs. Properties such as permeability and moisture holding capacity determine the rate and extent of movement (percolation) of transient soil solutions within the soil. Thus they may affect the time of contact or degree of miscibility and equilibration between the soil particles and the solution. For example, in a porous sandy soil equilibration may be minimal because of the rapid movement of solution through the soil at times of heavier rainfall. The soil moisture regime is likewise a factor that may influence the sensitivity of a soil. Imperfect, poor and very poor soil drainage classes reflect periods of excessive moisture within the soil that may be due to abnormal additions of water supplied surficially, by precipitation or by inflow from subsurface sources. Since the water from the latter source often contains dissolved minerals it may ameliorate the effects of acidic depositions. The mineralogy of a soil is another factor that may affect its sensitivity. If the more readily weatherable minerals are present, their weathering abets the buffering properties of the soil and in addition may replenish some of the nutrients mobilized by acidification.

Buffering capacity (BFC) is often referred to in qualitative terms. As used in this report BFC is defined as the quantity of acid (or base) required to change the pH of a given quantity of soil by one unit. In more expedient terms, it is inversely related to the magnitude of pH decrease a soil exhibits in response to a given increase in total soil acidity. Studies conducted elsewhere have shown that BFC is directly related to such soil parameters as clay content, organic matter content, base saturation, sum of exchangeable bases and cation exchange capacity (CEC). CEC is used as an index of BFC in this report.

All of the parameters that can be used to estimate BFC and the other soil properties and attributes that influence soil sensitivity are usually determined or otherwise evaluated for each kind of soil during a soil survey.

This project had two objectives. The first was to explore the feasibility of using soil survey information and data to develop criteria for classifying soils of the province into three broad categories of relative sensitivity to acidification. These categories are:

1. Soils most sensitive to acidification;
2. Soils of intermediate sensitivity to acidification;
3. Soils least sensitive to acidification.

The second objective was to develop procedures for using soil survey maps to show the areal distribution of soils classified according to their category of sensitivity.

The Sand River area was chosen for testing the application of the criteria and procedures that were developed. The following factors favoured the selection of this area:

1. A detailed reconniassance soil survey of the area was completed recently;
2. The area included a wide range of soils;
3. Considerable data were available on soils found in the area;
4. It included a good mix of forested and farm land;
5. There is a potential for considerable petroleum extraction development in the general area. A classification of the sensitivity of the soils could serve as one of the sources of information for predicting the possible effects of the impacts of these developments on different parts of the area.

The Sand River area (NTS Sheet 73L) is located in east central Alberta and encompasses approximately 1 215 000 ha. The principal towns, Cold Lake, Lac La Biche, and Grande Centre are

located in the area. Nearly 90% of the area consists of land and the remaining 10% lakes. A sizeable proportion of the southern half is farmed but the northern half is forested. The bedrock consists of Upper Cretaceous shales and sandstones but because the area has been glaciated the surficial materials are composed of morainic, glaciofluvial, glaciolacustrine and alluvial deposits. The weakly to moderately calcareous morainic deposits occupy nearly 80% of the land area. Fifty kinds of soils representing 38 soil series or series complexes in four taxonomic orders (Chernozemic, Luvisolic, Brunisolic and Gleysolic) of mineral soils and 10 series complexes or organic soils were identified in the area. With the exception of one subgroup of extremely acid organic soils, most of the other soils are medium acid to neutral in reaction. A master table of several pages shows the characteristics of each soil series and series complexes.

The laboratory derived data on soils by horizons for a profile or more of each of the soil series and series complexes included measurements of particle size distribution, organic matter content, pH, exchangeable bases, total acidity and CEC. The exchangeable bases and total acidity were determined by extracting with a salt solution buffered at pH 7.0. The sum of exchangeable bases and total acidity was used to obtain the CEC. Carbonate content, expressed as $CaCO_3$ equivalent, was determined on all the calcareous horizons. Mineralogical data were available for five profiles.

A somewhat subjective approach was used to define low, medium and high ranges in BFC for characterizing the broad categories of sensitivity. A review of pertinent literature from eastern North America and western Europe indicated that sandy soils were considered to be readily sensitive to acidification because of their low BFC and low capacity to retain exchangeable bases. On the other hand clayey soils were considered to exhibit low levels of sensitivity due to strong buffering properties. With these

conclusions in mind the data for various kinds of soils in Alberta were reviewed and revealed that sandy soils generally have CEC values lower than about 5 or 6 meq per 100 of soil. Clayey soils on the other hand have CEC values in the upper teens or considerably higher. These observations led to the adoption of the following ranges in CEC as characteristic of low, medium and high BFC:

Low BFC - CEC <6 meq

Medium BFC - CEC 6 to 15 meq

High BFC - CEC >15 meq

Similar ranges in CEC were used to define three comparable categories of sensitivity of soils in the preparation of a general map of soil sensitivity in eastern United States. It should be mentioned that similar ranges of sum of exchangeable bases were used to define the buffering qualities of soils in eastern Canada.

Plots of pH versus percent base saturation data for the Ae and AB-Bt horizons of 65 profiles of Orthic Gray Luvisolic soils from Sand River and other areas revealed that the rate of pH decrease relative to rate of increase of total acidity changed markedly at pH 5.2 to 5.4. Above this pH, that is, in the medium acid to neutral reaction range, the data plots showed that the soil pH decreased markedly with small increments in total soil acidity as indicated by the small decrease in base saturation. Below pH of about 5.2, that is, in the very strongly acid range, only a minimal decrease in pH is associated with a considerable increase in total acidity. This behaviour implied that CEC is an effective index of BFC of soils whose pH was 5.2 or higher but in very strongly acid soils the sum of exchangeable bases may be a more suitable indicator of the buffering qualities of such soils. It is concluded that while the CEC served as an effective index of BFC of soils whose pH is about 5.2 or higher its effectiveness could be refined further if the portion of CEC above pH 5.2, that is the pH-dependent portion, could be evaluated. It is recommended that a suggested method for this purpose be explored.

Because of the wide array of different kinds of soils that occur in the area the soil series and series complexes were assembled into eight groups called subcategories on the basis of similarities in BFC and sensitivity pertinent properties. Thus each of the three broad categories includes two or three subcategories. The grouping of soils into subcategories facilitated more specific descriptions of the soil properties and discussion of their predicted behaviour in response to acidification. It should be mentioned that the subcategory does not represent a heirarchical subdivision of the broad category.

The following guidelines were followed in use of criteria to classify individual soils into the broad categories and the subcategories of sensitivity:

1. The sensitivity of a soil is largely determined by its BFC and constitutes the major criterion for characterizing the three broad categories.
2. The BFC of soils is related to soil pH hence this parameter should be considered an important property in defining subcategories.
3. The upper horizons of the soil represent the portion of the soil profile that is most directly affected by surficial additions of anthropogenic acidity. The evaluation of the sensitivity of a soil should therefore be based primarily on the sensitivity of the horizons that constitute the topsoil in mineral soils. A thickness of 18 cm was assumed for the topsoil.
4. The BFC and sensitivity-pertinent properties and attributes of the subsurface horizons are expected to influence the sensitivity of the soil. They should be considered in defining subcategories. Arbitrary depths of 18 to 50 cm and in some soils to 100 cm were adopted as the depths to which the subsurface horizons would be characterized.

5. The prevalence and quality of subsurface water are important factors in determining the sensitivity of poorly and very poorly drained soils and should be so recognized in the definitions of appropriate subcategories.

These guidelines and a review of the data and other pertinent information available on the various soils, served as the basis for the following scheme of sensitivity classification that was developed for the area:

1. Soils most sensitive to acidification.
   - 1.1 Slightly to medium acid soils with low BFC throughout soil profile.
   - 1.2 Slightly to medium acid soils with low BFC in upper horizons and medium BFC in lower horizons.
2. Soils of intermediate sensitivity to acidification.
   - 2.1 Slightly to medium acid soils with medium BFC in upper horizons and medium to high BFC in the subsoil.
   - 2.2 Slightly to medium acid soils with medium to high BFC in the upper horizons and high BFC in the subsoil.
   - 2.3 Very strongly to extremely acid very poorly drained organic soils.
3. Soils least sensitive to acidification.
   - 3.1 Medium acid to mildly alkaline poorly to very poorly drained mineral and organic soils.
   - 3.2 Slightly acid to neutral soils with high BFC.
   - 3.3 Soils on relatively recent or slightly altered parent materials.

The additions of the anthropogenic acidifying materials onto the soil surface are areal in their distribution. By estimating the bulk density of soil by horizons, the sensitivity-pertinent data

available for profiles of each soil were converted from a weight to a volume basis. Thus CEC could also be shown on an area basis to depth intervals of 0 to 5, 5 to 18, 18 to 50 and in some cases 50 to 100 cm. The CEC values on an areal basis, expressed in equivalents (E = 1000 meq) per square metre and shown as E/m^2, were compiled in tabular form for each soil series and series complex. The sum of exchangeable bases expressed in E/m^2 units and the soil pH were also included in the compilation that was used to estimate the level of BFC by area and depth. These estimates of the level of BFC for each of the soils were used to place them into the appropriate subcategories defined in the sensitivity classification scheme developed for the area. The soil series and series complexes included in each of the subcategories were identified.

A computer-generated map on a scale of 1:250 000 was prepared to show by colour patterns the distribution of soils of the area classified according to their sensitivity subcategory. This procedure involved digitizing the soil survey map by quarter section cells that show the location and the identity of the soil of each quarter section. These digitized data were stored to facilitate future revisions in the sensitivity classification of any of the soils or parts of the area as deemed advisable.

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Judy Lorinczi assisted in soil data organization and processing, and performed the digitizing operation on the Sand River soil survey map. Pal Hooper compiled the manuscript using the Textform word processing format.

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1. INTRODUCTION

Rising energy needs resulting from industrial expansion have led to a progressively increasing consumption of fossil fuels. Consequently, through combustion and refining activities, the release of by-products generating acidity into the atmosphere have also increased. Likens et al. (1979) in a world wide overview of this problem noted that acidity in precipitation has increased sharply in recent decades and the areas affected are expanding. Rainfall with pH values of 3 to 4 in western and central Europe and 4 to 4.5 in eastern North America are commonplace. The principal cause is the emission of oxides of sulphur and nitrogen into the atmosphere. This man-induced change in the quality of the atmosphere (Kerr 1981), the deposition of the airborne materials, and the effects on terrestrial and aquatic ecosystems have been receiving increasing attention (Hutchinson and Havas 1980; Overrein et al. 1980; NRC-NAS 1981). The acidification of soils is one aspect of the effects on the terrestrial ecosystem that has caused considerable concern. It has also been recognized (Black 1981) that some of the constituents in the airborne material may serve as plant nutrients and thus have beneficial effects.

Anthropogenic impacts on soils, such as the use of fertilizers or the deposition of acidity-generating airborne contaminants may induce or accelerate acidification of the soils and thus adversely affect their quality as a medium for plant growth (McFee 1978; Nyborg 1978). The acidification of soils may also have some deleterious effects on the quality of effluent soil water (Johnson et al. 1981; Voigt 1980). The problem of these effects of accelerated acidification on agricultural soils in western Canada was reviewed recently by Hoyt et al. (1981). They stated that the use of nitrogen fertilizers is causing serious acidification but also postulated that in about 15 years the prevailing depositions of airborne emissions alone could be expected to decrease the pH by 0.25 unit in soils of extensive areas downwind from emission sources.

The objectives of the current project were; to develop criteria for using soil survey information and complementary laboratory-derived data to classify the soils of the province into three broad categories of relative sensitivity to acidification, and to work out procedures for preparing maps to show the distribution of soils according to their sensitivity. The Sand River area (Figure 1) was selected for testing the criteria and procedures. This report discusses and defines the criteria that were developed and how they were applied in the sensitivity classification of the soils of the Sand River area. The report also describes the procedures developed and used in preparing a computer-generated map, at a scale of 1:250 000, to show the areal distribution of soil sensitivity categories in the area.

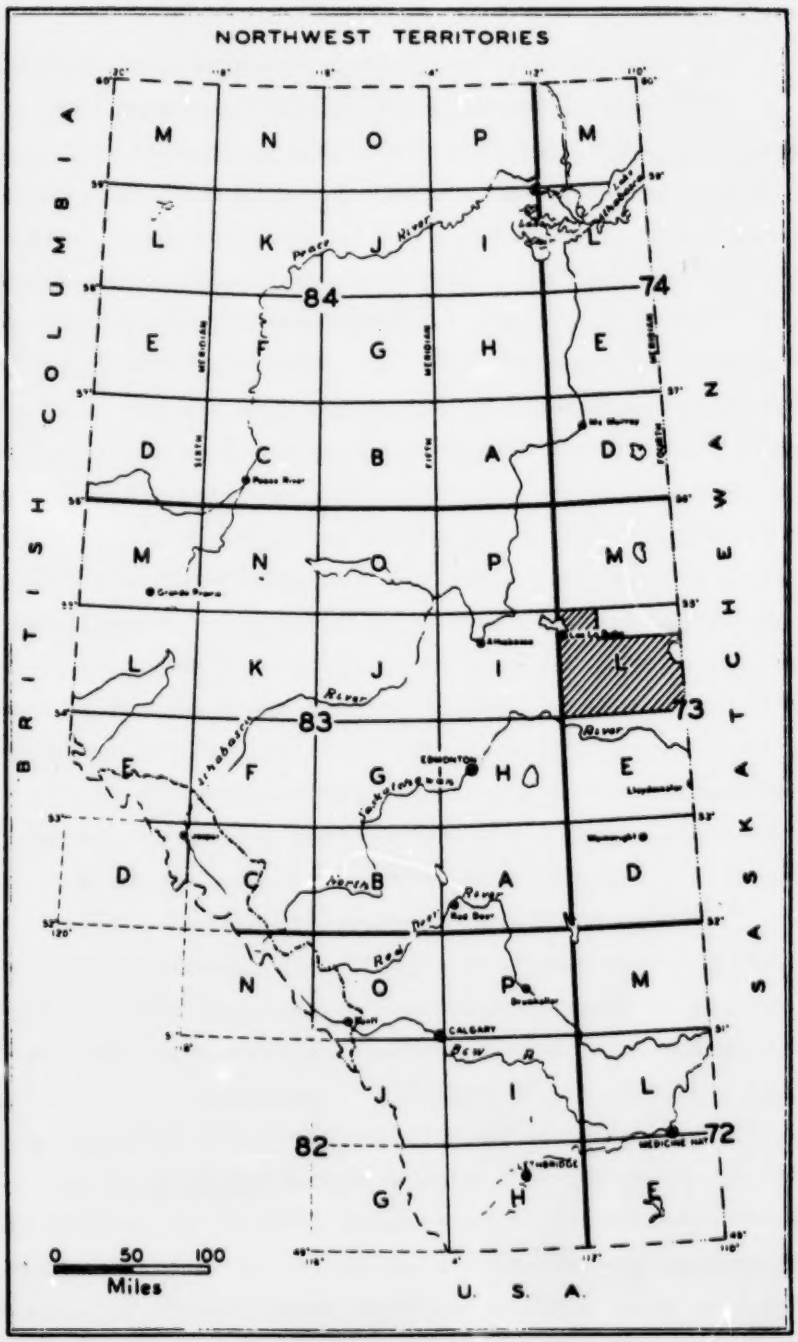

Figure 1. Sand River Soil Survey Area

2. ADDITIONS OF ANTHROPOGENIC ACIDITY-GENERATING MATERIALS

In Alberta, Sandhu et al. (1980) reported that emissions of anthropogenic sulphur (S), mostly as sulphur dioxide (SO_2), amounted to about 300 000 t annually. An additional estimated amount of about 33 000 t is contributed from natural sources. Within the atmosphere SO_2 is further oxidized to sulphate form (SO_4-S) leading to formation of such constituents as sulphate salts and sulphuric acid. This transformation proceeds more rapidly under summer conditions than during winter.

Impingement of the airborne materials on to soil, vegetation and water surfaces occurs by wet deposition, associated with precipitation (rain, snow and hail) and by dry deposition involving gravitational settling of particulates, and diffusion and absorption of small particulates and gaseous constituents. Deposition models, analysis of precipitation and gains in S content of soils were used to evaluate the amount of sulphur deposition in the province. The first two methods indicated annual depositions of 2 to 10 kg S/ha in the vicinity of emission sources. An appreciably higher quantity of deposition was indicated by increases in the S content in soils. As an example, Nyborg et al. (1980) reported that less than 4 kg/ha of S were deposited annually by precipitation but gains in S content in soils indicated depositions of 10 to 50 kg/ha. They also reported that in their investigations the deposition of S in remote areas was found to be about 1 kg/ha.

Generally the rainfall in areas near emission sources has pH values of 4.5 to 6.0 while in the remote areas the values range from 6.0 to 7.0 (Nyborg et al. 1980; Parker et al. 1978). Other rainfall constituents (such as Ca, Mg, K and Na) have been reported by Baker (1977) and Parker et al. (1978).

A number of studies have been made in Alberta regarding the acidifying effects of airborne depositions on soils. One of these studies in the Whitecourt and Edson areas (Shipley 1975)

reported few if any apparent affects. On the other hand the investigations conducted over an extensive area in south central Alberta indicated noticeable acidifying effects. The latter study, summarized by Nyborg and Walker (1977), showed a decrease of 0.1 to 0.2 units in pH of soils downwind from emission sources when they were exposed to depositions for several months. There was a decrease of 0.24 pH units when the soils were exposed for 26 months.

A more extensive field study was conducted by Laverty and Carson (1977). They systematically sampled soils for pH measurements on a grid pattern in an area nearly 30 km wide and of about similar length, downwind from two gas processing plants that had been in operation for 16 years. Test data for similar soils in the area indicated that prior to the plants the soil pH ranged from 7.0 to 7.5. After 16 years of exposure to emissions the soil pH values were from 0.1 to 1.0 unit lower. The maximum decrease in soil pH down to pH 6.4, was found in the zone 5 to 10 km downwind from the emission sources.

The use of ammonium (NH_4) based nitrogen (N) fertilizer is another source of acidity-generating additions to soils. There has been a marked expansion during the last decade in the use of such fertilizer in Alberta, increasing from 60 000 t in 1970 to 250 000 t in 1980 (Hoyt et al. 1981). The common forms of this fertilizer are; ammonium nitrate, ammonium sulphate, anhydrous ammonia, and urea. In their unaltered state they are not acid but in the soil they are converted to nitrates by the nitrification processes and generated acidity (HNO_3) (Penney and Henry 1976).

Hoyt et al (1981) cited studies giving a measure of the acidifying effects of N fertilizers on soils. In one such study (Nyborg and Mahli 1981) it was reported that when ammonium nitrate, urea and ammonium sulphate were applied for three years at a rate of 67 kg of N/ha the soil pH decreased by 0.20, 0.32 and 0.56 units. Another study (McCoy and Webster 1977) indicated that soil pH decreased from 5.8 to 5.3 where fertilizer consisting of 11 kg N/ha/yr and 9 kg S/ha/yr was applied over a period of 40 years.

3. ACIDIFICATION, ACIDITY AND SENSITIVITY OF SOILS

3.1 ACIDIFICATION OF SOILS

There are several sources of acidity, some external or anthropogenic and some indigenous to the soil system, that could cause acidification of soils. These sources will be identified and where feasible estimates given of the magnitudes of acidity they may generate. Thus some measure of their possible acidifying effects on the soil will be provided. These estimates of acidity, expressed in keq/ha/yr, are based on information from humid temperate regions.

3.1.1 Atmospheric and Soil Carbon Dioxide (CO_2)

Carbon dioxide when dissolved in water forms carbonic acid with a consequent production H^+

$$CO_2 + 2H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^{++}HCO_3^-$$

Bache (1980a) estimated that atmospheric water in equilibrium with CO_2 of the air would have a pH of about 5.6, and 50 cm of rainfall would generate 0.0125 keq/ha of H^+. In comparison, water in soils having 1% of CO_2 in the soil air would have a pH of 4.9. He also indicated that CO_2 in topsoil could generate about 1 keq/ha/yr of H^+. The acidity generating property of CO_2 is less effective in more acid soil enivronments since below a pH of about 4.9 it is released from solution (Ulrich 1980).

3.1.2 Soil Organic Matter

Soil organic matter consists of: (1) A complex mixture of plant and animal remains in various stages of decomposition; (2) Compounds synthesized from breakdown products; (3) Decomposed micro-organisms. For simplication they are divided into nonhumic and humic substances. The nonhumic category includes a variety of low-

molecular weight organic acids and several other groups of substances, most of which are fairly readily attacked by microorganisms and have a short survival rate (Schnitzer and Kodama 1977). The major portion of the organic matter of most soils however, consists of dark coloured, amorphous, chemically complex humic substances. These substances have acidic properties in that they have a high content of carboxyl, phenol hydroxyl and other functional groups that dissociate to produce H^+. Furthermore these humic substances attack and degrade soil minerals by complexing and dissolving metals. These include aluminum ions that upon hydrolysis produce H^+.

Ulrich (1980) did present some estimates of acidity production by organic matter under a beech forest in central Europe. He concluded that the form in which nitrogen was taken up by the trees was a determining factor in the production of acidity. Where N was taken up in nitrate form the production of acidity was zero, but it amounted to 4 keq/ha/yr if the N was taken up as NH_4. The organic matter in the latter case consisted of raw humus with a wide C/N ratio. Wiklander (1979) observed that leaching of organic acids from the acid litter of coniferous forest caused strong acidification of the underlying mineral soil.

3.1.3 Nitrification Processes

Both internal and external sources could contribute NH_4^+ to the soil system. Internally, NH_4^+ ions are produced by decomposition and mineralization of soil organic matter. The external source consists largely of ammonium based fertilizer but some NH_4^+ may also be added with depositions of airborne materials. Within the soil NH_4^+ is oxidized to nitrate (NO_3^-) by microbial processes (nitrification) to produce H^+. This may be shown schematically as

(Organic matter) $NH_4^+ \; 2O_2 \xrightarrow{\text{Nitrification}} NO_3^- + H_2O + 2H^+$

Theoretically 1 keq NH_4 would produce 2 keq H^+. If N is applied as an ammonium based fertilizer at 14 kg N/ha it should generate 2 keq/ha of acidity. However, the actual acidity produced under field conditions is less than the theoretical. Direct uptake of NH_4 by plants, volatilization, denitrification and a low ratio of excess base to N taken up by plants, reduce the net quantity of acidity that is produced (Pierre et al. 1970). The question of soil acidification by fertilizers in Alberta has been discussed more fully by Hoyt et al. (1981) and Penney and Henry (1976).

3.1.4 Indigenous or Added Sulphur Compounds

Sulphur is a constituent of the soil organic matter and plant material. It may also occur in the soil, in sulphate form, as a salt (e.g. $CaSO_4$) or as SO_4 anions absorbed by some soil components. Plants apparently take up S as SO_4 but it is subsequently converted to reduced states when incorporated into the organic compounds of the plant material and soil organic matter. Reuss (1976) indicated that the S turnover (cycle) in this system includes oxidizing and reducing transformations of inherent S by microorganisms that produce and consume H^+ ions to about an equal extent. No net change in acidity would result from these transformations unless H_2SO_4 or reduced or incompletely oxidized forms (S, SO_2, H_2SO_3) from external sources are added to the system. Oxidation of the added forms of S or H_2SO_4 would result in a net increase in acidity in excess of that appearing in the inherent S cycle of the soil-plant system. Irrespective of the oxidation-reduction states of the added S, the acidity produced by its complete oxidation would be two mol H^+ mol of S. On an equivalent basis 1 keq (16 kg) of added S would produce 1 keq of acidity. However Reuss does mention that in cases where the produced SO_4 ions may be taken up rapidly by plants the release of OH^- ions by the plants to maintain cation-anion balance would tend to

balance the extra acidity.

Under anaerobic soil environments SO_4 is reduced to sulphide to produce the gas H_2S or, in the presence of ferrous ions, the compound FeS_2. When a change to the aerobic soil environment occurs, acidity is produced by oxidation.

$$FeS_2 \xrightarrow{\text{oxidation}} Fe(OH)_3 + H_2SO_4.$$

Pyrite, a ferrous sulphide mineral, is found in a variety of rocks, generally in minor quantities. Where such rocks serve as the source of soil parent materials, the soils formed on these materials could be abnormally acid. Dark coloured carbonaceous shales tend to be rich in iron sulphide (Pettijohn 1975, pp. 282-284).

3.1.5 Acid Rainfall

According to estimates made by Bache (1980a) 50 cm of rainfall having a pH of 5.6 would add 0.0125 keq of acidity per hectare. A similar quantity of a pH 4.0 rainfall would deposit 0.50 keq/ha of acid.

3.1.6 Ferrolysis

This term refers to an acidifying process that may occur where well drained (aerobic) and water saturated (anaerobic) conditions in the soils alternate seasonally (Brinkman 1970). During the anaerobic stage the produced ferrous ions replace and thus mobilize some of the exchangeable bases. Subsequently during aerobic conditions the oxidation of ferrous ions at the exchange sites produces ferric hydroxide and H^+. This process could be a source of acidity in the poorly and very poorly drained soils.

3.1.7 Leaching as a Factor in Acidification of Soils

It has long been recognized that leaching is an acidifying process in climatic regions where the precipitation is such that some excess water is available for percolation. Wiklander (1979) identified several ways leaching contributes to soil acidification, mainly through depletion of bases and a resultant decrease in base saturation.

1. Percolating water dissolves salts in soils, transporting the solutes to lower horizons or out of the soil profile. Since this water normally contains some CO_2 the solubility of the carbonate salts is enhanced. Gasser (1973) had noted that the highest loss of calcium occurred in neutral or mildly alkaline soils.
2. The mobilization of soil exchangeable bases is governed by exchange reactions with the cations in the percolating water. The relative energy of bonding of soil exchange cations of the different exchangeable sites and those in the transient solution is one of the factors that influences the relative extent to which the different cations are displaced or adsorbed. As an example, Na^+ is more easily displaced by Ca_2^+ because of the much higher bonding energy of the latter. At a soil pH of about 5.5 or higher, hydrogen ions are very firmly bound and are very efficient in displacing exchangeable bases.
3. Leaching is conducive to more active weathering of soil minerals. By reducing the concentration of soluble weathering products the weathering reactions are less likely to be retarded. The processes involved not only contribute to loss of bases but in case of primary aluminosilicate minerals increase the aluminum content of the weathering residues.

3.1.8 Soil Attributes or Inputs that Retard Acidification

The following soil attributes tend to retard or counteract acidification of soils:

1. Free carbonates in soils have considerable capacity to neutralize H^+. As indicated by Bohn et al. (1979, p. 208) OH^- ions are produced by hydrolysis of carbonates such as $CaCO_3$ as shown by the equation

$$CaCO_3 + H_2O \rightleftarrows Ca_2^{++}HCO_3^- + OH^-$$

If all potential OH^- ions react with H^+, 2 keq of $CaCO_3$ would neutralize 1 keq of H^+. According to this reaction a layer of soil 5 cm thick with a bulk density of 1.3 and containing 1% $CaCO_3$ is capable of neutralizing 130 keq/ha of acidity.

2. Entrainment of slightly acid to mildly alkaline dust or other constituents is a common occurrence in the cultivated portions of the Interior Plains (Caiazza et al. 1978; Gorham 1976). During 2 days, May 7, 8, 1981 the Edmonton area experienced considerable dust fall from southeasterly winds that entrained the airborne materials in southeastern Alberta. Collected samples of the dust had a pH of 6.9. Such materials, according to Gorham, would tend to neutralize some of the airborne and surficial additions of acidity and thus reduce their acidifying effects. It was also indicated by Bache (1980b) and Wiklander (1975) that the presence of neutral salts in acidity inputs have a moderating influence on the acidifying effects.

3. The poorly and very poorly drained soils, both mineral and organic, occupying lower lying landscape positions are susceptible to surface and subsurface inflow of

minerotrophic water. Such waters tend to neutralize or retard the acidification of these soils. This effect is especially evident in some organic soils. The soils of fens generally have pH values of about 6.0 or higher. They have a high content of exchangeable bases while sphagnum bog soils are considerably more acid and have relatively low content of bases. Gorham (1967) and Sparling (1966) feel that the prevalence of minerotrophic water in fens is at least one of the factors contributing to the higher base status and pH in fen soils.

4. Recycling of nutrients by vegetation can compensate for some of the leaching losses and mollify to a varying extent the effects of acidification as cited by McFee et al. (1976), Ulrich (1980) and Wiklander (1979). In general, deciduous trees are more effective in this respect than coniferous.

3.1.9 Distribution of Acidification in the Soil Profile

The vertical distribution of the acidic inputs in the soil is a factor that should be considered when evaluating the acidifying effects on the soil. Some of the inputs are largely surficial, some are distributed in the upper horizons and some may be distributed throughout the soil. Where the additions are on or at the surface only the surficial horizon of the soil would be involved so the relative effects would be more localized and hence more pronounced in relation to the quantity of the input. This condition would apply to airborne depositions and to some extent plant residue accumulations. The acidifying effects through nitrification are likely to be distributed throughout the horizons having appreciable organic matter or, in cases where N fertilizers had been applied, throughout the depth of mixing. Broadcast applications of N fertilizer could cause pronounced acidity

at the surface. Fox and Hoffman (1981) reported that the annual applications of 101 kg/ha of N as NH_4NO_3 lowered the soil pH from 6.73 to 6.20 in the 0 to 2.5 cm layer after 5 years.

3.2 SOIL ACIDITY

By definition acidification increases the total acidity of the soil and reduces pH. As shown by Coleman and Thomas (1967) soil acidity is complex. Furthermore its acidic properties above a pH of about 4.2 are due almost entirely to H^+ (actually H_3O^+ when in solution). The H^+ is derived through hydrolysis of a sequence of soluble, exchangeable, or adsorbed hydroxy Al ion species or to H^+ released by dissociation of the carboxyl and phenolic hydroxyl functional groups of the humic materials. The Al ions range from Al_3^+ below a pH of about 4.2, to monomeric hydroxy Al ions below a pH of about 5.2 to 5.5, to polymeric hydroxy Al forms at higher pH. The monomeric ions behave as exchangeable cations. They are of particular significance in the strongly to very strongly acid mineral soils since, as mentioned by Coleman and Thomas, the release and readsorption of H^+ during hydrolysis shown by the simplified equation could produce both acidifying and neutralizing effects:

$$Al_3^+ + H_2O \rightleftarrows AlH_2O^+ + H^+$$

This reaction and the possible release of Al by H^+ from soil minerals likely account for the pronounced buffering observed in mineral soils at a pH of about 5.0. Comprehensive discussions of the significance of aluminum ions in acid soils has been presented by Jackson (1963) and Frink (1973). The parameters involved in defining soil acidity are identified as follows in the following subsections 3.2.1 to 3.2.5.

3.2.1 Total Acidity

This refers to the combined total content in the soil of H^+ plus the undissociated forms of acidity in the soil. Quantitatively it is equal to the amount of base such as NaOH that is required to raise the pH of a given quantity of soil to pH 7.0 or more commonly to pH 8.2. It is expressed in meq/100 g of soil. McLean et al. (1966) found that the lime requirement of soils has a strong positive correlation with total acidity.

3.2.2 Exchangeable Acidity

This represents the portion of total acidity that can be extracted from the soil by a concentrated (usually 1.0 *M*) unbuffered solution of neutral salt such as KCl or NH_4Cl. Since the salt solution is unbuffered it acquires the pH of the soil so the acidity extracted represents the portion of total acidity that can be exchanged at the pH of the soil. Like total acidity it is shown in meq/100 g of soil.

3.2.3 Residual Acidity

The residual acidity is that portion of total acidity that is not extracted with unbuffered salt solutions and hence constitutes the difference between total and exchangeable acidity.

3.2.4 Degree of Acidity

The total acidity dissociates to a small extent, the dissociation producing H^+, which determines the degree of acidity. The concentration of the produced H^+, measured as pH, expresses the degree of acidity. Many of the chemical and biochemical reactions and processes, such as weathering, are more sensitive to the degree of acidity rather than total acidity. The determination of pH, while it appears to be a simple operation, is influenced by a number of factors (Russell 1973, pp. 121-128). Presence of even small concentrations of salts in the soil solution

or in soil-water mixtures used for measuring pH lowers pH values. This effect may be critical when small changes in pH are used to evaluate changes in the degree of acidity of soil.

3.2.5 Strength Categories in Soil Acidity

In chemistry, acids that are dissociated completely or near so to H^+, are called strong acids, whereas those that dossociate to a small degree are said to be weak. An analogous approach, as shown below, has been used to characterize the dissociating qualities (strength) of the total acidity of soils. The likely sources of H^+ in each strength category, as indicated by Buol et al. (1980, pp. 69-70); Coleman and Thomas (1967); and Jackson (1963) are listed for each of the strength categories of soil acidity.

3.2.5.1 Strong Acids (pH about 4.2 and lower). Acid sources commonly occurring in this group are: H_2SO_4, from oxidation of external S or indigenous sulphides; HNO_3, from heavy applications of ammonium based fertilizer; and strong acid functional groups in the organic fraction.

3.2.5.2 Weak Acids (pH about 4.3 to 5.2 to 5.5). Sources of the acids in this group are monomeric hydroxy Al and the carboxyl functional groups of the organic fraction. H_2CO_3 may be a source in the upper range of pH. The acidity in the weak acid range of mineral soils is largely due to the prevalence of monomeric hydroxy Al ions. Because of the buffering effects associated with the hydrolysis of these ions the pH of mineral soils commonly does not decrease below about 4.2 unless free salts or strong acids are present.

3.2.5.3 Very Weak Acids (pH 5.3 to 5.5 to about 7.0). Sources of these acids are: polymeric hydroxy Al; carboxyl, and other functional groups of organic fractions; H_2CO_3.

3.2.6 Terminology Commonly Used for Acidity of Soils

The following terminology is commonly used to denote the classes of acidity of the soils. This refers to their degree of acidity.

Class	
Extremely acid	<4.5
Very strongly acid	4.6 to 5.0
Strongly acid	5.1 to 5.5
Medium acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3

3.3 SOIL SENSITIVITY

There appears to be some differences of opinion among workers as to what resultant changes in soils should be considered in estimating their sensitivity to effects of acidification. Bache (1980b) considered the sensitivity of a soil as its susceptibility to an observed degree of change in its base saturation in response to a given input of acidity. McFee (1980) had a somewhat broader concept of sensitivity. He felt that sensitivity of a soil should not only refer to its susceptibility to the degree of change in its pH and base saturation but should also include a consideration of how such effects on the soil may affect the ecosystem. A somewhat comparable concept was presented by Voigt (1980). In this report, sensitivity is considered to be an expression of the susceptibility of different soils to relative degrees of change in their pH, base saturation and mobilization of exchangeable cations in response to given inputs of acidity.

The level of sensitivity of a soil reflects the integrated result of several factors of which the buffering capacity (BFC) and pH are the most significant. In addition to these two parameters other soil properties or attributes influence the degree to which the soil responds to acidity inputs. Such properties as permeability and moisture holding capacity determine the rate and extent of movement (percolation) of transient soil solutions within the soil. Thus they may affect the time of contact or degree of miscibility and equilibration between the soil particles and the solution. As an example, in a porous sandy soil equilibration may be minimal because of the rapid movement of solution through the soil at times of heavier rainfall or melting of snow. The soil moisture regime is likewise a factor that may influence the sensitivity of a soil. Imperfect, poor and very poor soil drainage classes reflect periods of excessive moisture within the soil that may be due to abnormal additions of water supplied surficially, by precipitation or by inflow from subsurface sources. Since the water from the latter source is often minerotrophic it may ameliorate the effects of acidic depositions. The mineralogy of a soil is another factor that may affect its sensitivity. If the more readily weatherable minerals are present, their weathering abets the buffering properties of the soil and in addition may replenish some of the nutrients mobilized by acidification (Johnson et al. 1981).

Bache (1980a) defined BFC as the amount of acid or base required to change the pH of a given quantity of soil by 1 pH unit. BFC is determined by several soil parameters. Nilsson (1977) reported that BFC correlated positively with several soil parameters such as clay content, loss on ignition, cation exchange capacity (CEC), percent base saturation and sum of exchange bases, of which the latter two showed the highest correlation. These relationships permit estimation of BFC where pertinent data on the parameters are available. Wang and Coote (1980) used the sum

of exchangeable bases to estimate BFC while McFee (1980) used CEC as an indicator of BFC to define the sensitivity of soils of the eastern United States. Bache (1980a) indicated that CEC is the main factor that determines BFC.

A review of literature has shown that BFC is considered to be the most important soil parameter of the soil that determines its sensitivity. In general, sensitivity is inversely related to BFC. The magnitude of BFC of a soil however, is influenced by the pH of that soil. According to Bache (1980a), Fieldes (1962) and Wiklander (1979) a mineral soil that is similar otherwise has a higher BFC in the very strongly to strongly acid range than it has at a higher pH. This is attributed to the buffering effects of hydrolysis of exchangeable hydroxy Al ions in the more acid range.

4. THE SAND RIVER AREA

The soil survey area shown in Figure 1 covers all of NTS sheet 73L except for the northeastern section occupied by the Primrose Air Weapons Range. The NTS sheet 73L extends from 54° to 55° North Latitude and from 110° to 112° West Longitude. Approximately 1 215 000 ha (3 000 000 acres) were surveyed of which slightly over 10% consists of lakes.

4.1 CLIMATE

The climate of the area is continental with warm summers and cold winters. According to Environment Canada (1975) data for the Cold Lake and Lac La Biche stations the mean annual temperature is between 1°C and 2°C. Table 1, taken from the Sand River soil survey report Sand River Area 1975, shows the mean values for temperature and precipitation by months. The frost-free period ranges from about 90 days in the southern part to about 60 days in the north. The soil moisture conditions common to the area as indicated in the soil survey report are that the water deficit is low since the major proportion of the rainfall occurs during the summer months, a period when the extraction of soil moisture by plants is at a maximum.

Some storms of relatively higher rainfall do occur in the area. It is anticipated that such rainfall would lead to saturation of the soil to some depth, a condition that would be conducive to greater percolation and associated leaching. This phenomenon may be especially significant in soils of low moisture holding capacity and rapid permeability or when soils are at or above field capacity as they may be following snowmelt.

4.2 VEGETATION

A large part of the area occurs in the Mixedwood Section of the Boreal Forest Region (Rowe 1972). In the Sand River soil survey report, Kocaoglu reports that aspen and balsam poplar are

Table 1. Monthly and annual temperature and precipitation at Lac La Biche and Cold Lake.

	LAC LA BICHE					COLD LAKE				
	Daily Temp. (C)			Precipitation		Daily Temp. (C)			Precipitation	
	Mean	Max.	Min.	Rain mm	Snow cm	Mean	Max.	Min.	Rain mm	Snow cm
January	-17.0	-12.4	-21.6	0.5	25.7	-18.9	-14.1	-23.8	0.2	24.9
February	-14.1	-8.7	-19.4	0.2	18.5	-13.6	- 8.1	-19.2	0.2	17.8
March	- 7.7	-2.3	-13.2	1.8	20.3	- 7.8	- 2.1	-13.5	3.3	22.9
April	2.3	8.1	- 3.4	18.0	18.0	0.8	7.4	- 3.6	9.9	17.0
May	10.1	16.3	3.8	30.5	4.1	10.1	16.4	3.7	31.8	4.1
June	14.1	19.8	8.4	67.1		13.7	19.6	7.8	83.6	
July	16.8	22.6	11.1	71.9		17.1	22.9	11.2	88.6	
August	15.3	20.9	9.7	69.6		15.4	20.8	10.0	79.8	
September	10.0	15.2	4.8	44.5	1.3	10.0	15.2	4.7	40.6	
October	4.1	9.1	- 1.0	7.9	11.9	4.3	9.5	- 0.9	9.1	9.9
November	- 6.0	- 2.0	-10.0	2.5	22.1	- 5.6	- 1.5	- 9.7	2.3	23.1
December	-13.1	- 8.5	-17.6	0.8	25.9	-11.2	- 6.6	-15.9	1.3	26.4
Year	1.2	6.5	- 4.0	315.2	147.8	1.2	6.3	- 4.6	350.8	146.1

the dominant components of the cover while jack pine is commonly found on the drier sandy soils and black spruce and tamarack are prevalent in areas of poor drainage. Balsam fir, paper birch and white spruce also occur in the area. The northern fringe of the Aspen Grove Section (Rowe 1972), consisting of an intermingling of aspen groves and grassland, extends into the southern part of the area. A sizeable proportion of the southern and southwestern parts of the area is agricultural land.

4.3 BEDROCK GEOLOGY

The following statement from the Sand River soil survey report (Sand River Area 1975) is a brief description of the bedrock geology of the area:

The bedrock in this area is composed of slightly consolidated to unconsolidated bentonitic shale and sandstone of lower Upper Cretaceous age (Green 1972). The Lea Park Formation underlies most of the area and is composed of gray blue and black shale with clay ironstone concretions and some fine-grained sandstone beds and lenses. The shales of the Lea Park Formation correspond to the shales of the La Biche Formation in northeastern Alberta (Green 1972). The Belly River Formation underlies the southwestern corner of the area and is composed of nonmarine, gray to greenish gray, thick bedded, feldspathic sandstone; gray, clayey, siltstone; gray and green mudstone; and a concretionary ironstone bed (Green 1972).

4.4 SURFICIAL MATERIAL

All of the general region has been glaciated by Keewatin ice (Tiwatinaw [Geology] 1972) and according to Sand River Area (1975) glacial till constitutes the surficial material of most of the soil survey area. His report also indicates that other kinds of surficial materials such as glacial or post glacial lacustrine, fluvial, aeolian, alluvial, and deltaic sediments and in certain landscape

conditions, thick organic accumulations are also of an appreciable extent. Based on the magnitude of areas of the various kinds of soils mapped, the following is the relative extent of the different categories of surficial materials expressed as percent of the land area (1 090 000 ha).

Surficial Material	%
Glacial Till	75.3
Lacustrine Sediments	2.4
Sandy Aeolian and Alluvial Deposits	7.7
Deltaic Deposits	0.1
Glaciofluvial Deposits	2.2
Thick Organic Accumulations	11.7
Relatively Recent Alluvium	0.6

Information regarding some of the chemical properties and particle size distribution of the different materials can be derived from the laboratory data and the descriptions of the various kinds of soils presented by Kocaoglu and the data shown in Tables 2 and 3 of this report. These data indicate that the glacial till and frequently the lacustrine sediments are calcareous. It is also possible that mention of this property in some of the other materials may have been omitted. It is anticipated that because of the more or less ubiquitous presence of carbonates in the mineral surficial materials the waters emanating as subsurface discharge are neutral or mildly alkaline in reaction.

Table 4 presents mineralogical data compiled from the more extensive data generated by Abder-Ruhman (1980) on five soil profiles derived from glacial till in the Sand River soil survey area. In addition to other information these data indicate that the fine earth fraction (<2mm) contains significant quantities of Na-Ca feldspars, amphiboles and trioctahedral mica, minerals considered to be of the more easily weatherable varieties.

Table 2. Physical and chemical data for selected sample profiles of mineral soils by subgroups found in the Sand River area.

Horizon	Depth cm	Organic Carbon Content %	Sand, silt and clay contents %			pH (H2O)	CEC* meq/100g	Bases** meq/100g	CaCO3 Equiv. %
			Sand	Silt	Clay				
		A profile of the Fergy series, Eluviated Black Chernozem							
Ahp	0-18	4.52	43	39	18	6.8	28.8	25.1	-
Ae	18-20	1.06	39	45	16	6.4	13.5	11.8	-
Bt	20-46	1.07	36	37	27	6.1	19.5	17.9	-
BC	46-69	-	44	35	21	6.2	15.7	14.6	-
Ck	69-89	-	53	29	18	7.0	-	-	7.1
		A profile of the Kehiwin series, Orthic Dark Gray Chernozem							
Ahp	0-25	3.69	41	40	19	7.1	25.6	25.6	-
Ae	25-30	0.80	38	39	23	7.1	15.7	15.7	-
Bt1	30-36	0.83	36	37	27	6.8	19.9	18.8	-
Bt2	36-61	0.75	36	38	26	6.6	18.8	17.7	-
BC	61-66	-	38	37	25	7.2	-	-	0.9
Cca	66-127	-	38	38	24	7.9	-	-	11.8
Ck	127+	-	39	39	22	7.9	-	-	6.5
		A profile of the Winston series, Dark Gray Luvisol							
LH	3-0	-	-	-	-	7.2	31.7	31.7	0.4
Ah	0-6	4.31	34	39	17	7.3	24.9	24.9	0.2
Ae	6-20	0.71	30	57	13	6.5	6.2	6.2	-
Bt1	20-38	0.99	18	24	58	5.1	34.9	30.6	-
Bt2	38-58	1.03	10	27	63	6.5	36.6	35.4	-
BCk	58-81	-	14	28	58	7.3	36.9	36.9	5.6
Ck	81-102	-	14	29	57	7.7	-	-	10.0
		A profile of the La Corey series, Orthic Gray Luvisol							
LH	8-0	10.25	-	-	-	6.2	34.8	28.2	-
Ae	0-9	0.90	38	48	14	6.0	7.7	5.8	-
BA	9-14	0.50	35	39	26	5.6	11.4	9.2	-
Bt1	14-44	0.41	36	34	30	5.0	15.4	13.0	-
Bt2	44-81	0.36	34	37	29	5.0	17.1	14.7	-
BC	81-97	0.46	27	28	45	6.9	20.6	20.3	-
Ck1	97-130	-	37	37	26	7.7	-	-	5.5
Ck2	130+	-	44	35	21	7.6	-	-	9.7

continued...

Table 2. Concluded

				A profile of the Athabasca series, Orthic Gray Luvisol					
LH	5-0	-	-	-	-	5.3	41.4	25.2	-
Ae	0-10	0.32	32	61	7	5.2	6.0	3.6	-
Bt1	10-23	0.44	38	31	31	4.7	16.4	12.8	-
Bt2	23-36	0.61	26	26	48	5.1	23.2	20.2	-
BC	36-58	-	40	31	29	5.2	17.3	15.1	-
C1	58-86	-	38	32	30	5.8	18.4	17.3	-
C2k	86-107	-	33	31	36	7.2	-	-	3.5
				A profile of the Nicot series, Eluviated Eutric Brunisol					
LH	5-0	-	-	-	-	6.3	35.4	27.6	-
Ae	0-5	0.38	90	8	2	6.2	3.6	2.5	-
Bm1	5-18	0.32	85	13	2	6.3	3.3	2.0	-
Bm2	18-38	0.15	86	12	2	6.3	3.5	2.7	-
Bm3	38-66	0.09	96	2	2	6.4	3.0	2.6	-
C	66+	-	96	2	2	6.6	2.7	2.3	-
				A profile of the Mapova series, Humic Eluviated Gleysol					
Ah	0-13	3.39	50	32	18	6.6	20.6	18.9	-
Aeg	13-20	0.20	55	37	8	7.1	4.9	4.6	-
Btg	20-33	0.39	41	22	37	6.5	20.0	19.3	-
BCg	33-61	-	44	24	32	6.6	17.7	17.0	-
Ckg1	61-94	-	44	27	29	7.4	-	-	3.5
Ckg2	94+	-	43	27	30	7.6	-	-	6.2

* CEC = Cation Exchange Capacity determined at pH 7.0
** Bases = sum of exchangeable bases (Ca, Mg, Na, K)

Table 3. Organic carbon content, pH and cation exchange data for selected profiles of three organic soils found in the Sand River area.

Horizon	Depth cm	Organic Carbon Content %	pH (H20)	CEC* meq/100g	Bases** meq/100g
		A profile of the Stebbing complex, Fibrisol Great Group			
Of1	0-33	38.7	3.4	107.3	21.7
Of2	33-142	44.8	3.5	136.0	18.0
Of3	142-157	45.8	-	119.1	25.7
		A profile of the Manatokan complex, Mesisol Great Group			
Of	0-8	41.4	6.5	86.1	73.3
Om1	8-74	43.6	6.1	80.5	49.8
Om2	74-102	9.8	5.9	24.0	14.0
IIC	102+ (sand)		-	-	-
		A profile of the Bonnie complex, Humisol Great Group			
Oh1	0-13	35.6	5.6	122.9	76.0
Om	13-64	37.9	5.8	110.4	69.2
Oh2	64-91	29.7	5.9	109.8	73.3
Oh3	91-152	45.3	5.6	121.6	77.9

* CEC = Cation Exchange Capacity determined at pH 7.0.
** Bases = sum of exchangeable bases (Ca, Mg, Na, K).

Table 4. Contents of mineral species (%) in fine earth (<2 mm) fraction of 5 soil profiles derived from till in the Sand River area.*

Horizon	Depth cm	Quartz	Feldspars K	Feldspars Na-Ca	Mica	Amphiboles	Vermiculite	Chlorite	Kaolinite	Smectite	Others
Eluviated Black Chernozemic - Fergy Series (Site 5)											
Ah	0-23	62.4	6.8	9.7	5.8	1.2	4.1	0.3	6.4	2.4	0.9
Ae	23-31	65.0	6.3	8.7	5.7	1.0	1.6	0.2	6.1	4.7	0.8
Bt1	31-59	55.6	5.1	7.8	8.6	1.0	2.4	0.1	7.9	10.7	0.8
Bt2	59-83	56.3	5.1	8.3	8.8	1.2	2.0	0.3	7.9	9.1	0.9
BC	83-100	56.0	5.8	8.8	8.8	1.4	1.7	0.3	7.2	8.9	1.0
Cca	100-125	53.5	5.8	9.8	9.0	1.6	1.5	0.3	8.8	8.7	1.0
Orthic Gray Luvisol - Tomson Series (Site 1)											
IAe	0-25	73.7	7.6	12.0	1.9	1.1	0.2	0.1	1.4	0.6	1.4
IIAB	25-37	58.4	6.6	10.2	7.8	0.9	2.2	0.3	6.6	6.1	0.9
IIBt1	37-62	52.4	5.9	9.8	10.7	1.1	3.1	0.1	5.9	10.3	0.7
IIBt2	62-87	50.9	6.1	9.7	10.5	1.4	3.2	0.1	7.0	10.1	0.9
IIBCk	87-98	46.8	6.0	9.6	12.3	1.6	3.6	0.4	8.1	10.8	0.8
IICca	98-125	45.3	6.1	9.5	11.8	1.8	2.3	0.4	10.9	10.9	1.0
Orthic Gray Luvisol - Athabasca Series (Site 4)											
Ae	0-15	65.7	6.5	7.9	6.1	1.4	1.6	0.3	6.3	3.3	0.9
AB	15-30	50.2	4.4	5.7	10.3	1.2	5.3	0.5	9.3	12.3	0.8
Bt1	30-71	44.8	4.0	6.1	13.8	1.1	5.2	0.1	7.8	15.1	0.9
Bt2	71-98	43.5	4.7	6.5	15.0	1.1	6.0	0.1	6.7	15.2	1.3
Ck	98-124	45.8	4.6	7.1	12.2	1.2	4.6	0.5	9.1	13.7	1.1
Dark Gray Luvisol - Spedden Series (Site 2)											
Ahe	0-20	62.2	7.2	10.2	6.1	1.5	3.0	0.1	6.3	2.3	1.1
Ae	20-28	67.6	7.0	10.5	4.6	1.5	0.5	0.2	4.8	2.2	1.1
Bt	28-52	50.8	5.5	8.5	9.4	1.3	2.2	0.4	9.0	11.7	1.2
Cca1	52-87	49.3	6.4	9.6	9.5	2.1	2.4	0.4	9.3	9.8	1.2
Cca2	87-125	49.9	6.9	10.0	9.3	2.0	3.1	0.7	8.6	9.1	1.3
Dark Gray Luvisol - Spedden Series (Site 3)											
Ahe	0-8	65.7	8.0	11.5	5.7	1.4	1.9	<0.1	3.4	1.3	1.1
Ae	8-18	64.3	8.2	11.8	4.8	1.8	0.8	0.2	4.3	2.5	1.3
AB	18-31	47.9	6.2	8.9	10.6	1.1	3.4	0.1	8.3	12.4	1.1
Bt1	31-53	47.7	6.3	9.6	10.4	1.2	3.9	0.1	7.4	12.4	1.0
Bt2	53-78	48.4	6.6	9.3	9.9	1.2	3.4	0.1	8.6	11.6	0.9
BCk	78-93	51.3	6.7	10.0	9.1	1.6	1.9	0.3	8.4	9.2	1.5
Cca	93-120	51.0	6.7	10.5	9.6	1.6	2.4	0.1	8.6	8.2	2.5

*Compiled from data in Abder-Ruhman (1980)

The general nature of weathering in Orthic Gray Luvisol soils has been discussed by Pawluk (1961).

Texturally most of the glacial till consists of loams and clay loams and is classed as fine loamy. Glacial till of this texture is generally moderately to slowly pervious to water. While the till is largely fine loamy it is mantled in some areas by a thin (generally less than 75 cm thick) overlay of sandy material. In such cases the derived soils may be rapidly pervious in the upper part and also, because of the lower clay content, they likely have lower CEC and hence lower capacity to buffer acidifying effects.

5. SOILS OF THE SAND RIVER AREA

A reconnaissance soil survey of the area (Kocaoglu 1975) provided a report and soils map on a scale of 1:126 700. These documents served as the primary sources of information on soils of the area. A number of soils found in the Sand River area are similar to some soils that occur in the Tawatinaw area adjoining to the west. The report and map for the latter area (Tiwatinaw [Soil Survey] 1972) was also an important source of information. The following information consists largely of a summary of the more extensive information included in the soil survey report by Sand River Area (1975).

The characteristics and properties of soils reflect the integrated effect of climate, vegetation, topography and moisture regimes acting through time on the parent materials from which the soils are derived. The differences in topography, moisture regimes, vegetative cover and the types of parent materials (surficial materials) in which the soils have developed resulted in a considerable variety of soils. During the soil survey the various kinds of soils were classified first into five broad categories (Orders) and subsequently into more precise lower categories, the Subgroups and Series, according to widely recognized taxonomic criteria described in the soil survey report. It is strongly recommended that this report and the one for the Tawatinaw area (Tiwatinaw [Soil Survey] 1972) be consulted for more comprehensive discussions of these soils. In particular their classification and the physical and chemical properties pertinent to their potentials, management and behaviour under agricultural and non-agricultural uses.

A total of 48 soil series or soil series complexes and two land types were mapped in the area. These are shown in Table 5. This table identifies the parent materials, moisture regime and the soil map symbol and relative extent of each soil series or series complex in the area. A comparable list of

Table 5. Soils of the Sand River area; their characteristics, taxonomic classification, relative extent and subcategory of sensitivity to acidification.

Soil Symbol	Soil Name	Taxonomic Classification	Parent Material	Texture		Drainage Class	% of Land Area	Acidification* Sensitivity Subcategory
				Upper Horizons	Lower Horizons			
ALL	Alluvium	Undifferentiated	Sandy to clayey alluvium, may contain gravel and cobbles	sandy to sandy clay	sandy to sandy clay	Poorly to rapidly drained	0.6	3.3
AMK	Amisk	Eluviated Eutric Brunisol	Sandy alluvium or aeolian material	loamy sand	loamy sand	Well to rapidly drained	0.2	1.1
ABC	Athabasca	Orthic Gray Luvisol	Fine-loamy, weakly calcareous glacial till	Loam	clay loam or loam	Moderately well drained	13.6	2.1
BLY	Belloy	Dark Gray Luvisol	30 to 75 cm sandy alluvium over weakly calcareous glacial till	Loamy sand and sandy loam	Sandy loam to loam	Moderately well to rapidly drained	0.3	1.2
BL	Birkland	(Organic) Fibrisol	Moderately thick** fibric and forest peat over loamy glacial till or sandy to silty sediments			Poorly to very poorly drained	0.9	2.3
BN	Bonnie	(Organic) Humisol	Thick humic fen peat, sandy to silty sediments below 160 cm			Poorly to very poorly drained	0.3	3.1
CT	Chatwin	(Organic) Mesisol	Moderately thick to thick mesic fen or forest-fen peat over fine-loamy glacial till			Poorly to very poorly drained	0.2	3.1
CUN	Clouston	Orthic Gray Luvisol	Glaciofluvial material	Loamy sand and sandy loam	gravelly sandy loam	Rapidly drained	0.2	1.1
COA	Codesa	Eluviated Eutric Brunisol, Orthic Gray Luvisol	30 to 75 cm of coarse-loamy alluvium over fine-loamy weakly calcareous glacial till	Loamy sand and sandy loam	Loam	Well drained	3.5	1.2
COD	Codner	Orthic Humic Gleysol	Fine-silty, weakly calcareous lacustrine material	Loam and silt loam	Silt loam	Poorly drained	<0.1	3.1

continued...

Table 5. Continued.

Soil Symbol	Soil Name	Taxonomic Classification	Parent Material	Texture		Drainage Class	% of Land Area	Acidification* Sensitivity Subcategory
				Upper Horizons	Lower Horizons			
DKN	Daken	Rego Humic Gleysol	Sandy alluvium or aeolian material	Loamy sand and sandy loam	Sandy loam or loamy sand	Poorly drained	0.6	3.1
EDW	Edwand	Eluviated Eutric Brunisol	Sandy-skeletal glaciofluvial material	Loamy coarse sand	Loamy coarse sand or sand	Rapidly drained	1.9	1.1
EGO	Egremont	Gleyed Dark Gray Chernozemic	Fine-loamy, moderately to strongly calcareous glacial till	Loam	Clay loam	Imperfectly drained	0.2	3.1
FWT	Fawcett	Dark Gray Luvisol	Fine-silty, moderately to strongly calcareous lacustrine materials	Loam and silt loam	Silty clay loam	Well drained	0.3	2.2
FRY	Fergy	Eluviated Black Chernozemic	Fine-loamy, moderately to strongly calcareous glacial till	Loam	Clay loam	Well drained	3.2	3.2
GBL	Gabriel	Dark Gray Luvisol	30 to 75 cm of sandy alluvium or aeolian material over moderately to strongly calcareous glacial till	Loamy sand and sandy loam	Sandy loam to loam	Moderately well to rapidly drained	<0.1	1.2
GOY	Glory	Orthic Gray Luvisol	Fine-silty deltaic material with thin bands of coarse textured material	Sandy loam, loam, and silt loam	Silt loam and loam	Well drained	<0.1	2.1
GOG	Good Ridge	Orthic Gray Luvisol	Coarse-loamy, moderately to strongly calcareous glacial till	Sandy loam and loam	Silt loam, loam, sandy loam	Well drained	1.4	2.1
GDI	Grandin	Orthic Gray Luvisol	Fine-clayey, weakly calcareous glacial till	Sandy loam to clay loam	Clay loam	Moderately well drained	4.8	2.1
GMT	Grosmont	Dark Gray Luvisol	Fine-loamy, weakly calcareous glacial till	Silt loam to clay loam	Clay loam	Moderately well drained	0.9	2.2

continued...

Table 5. Continued.

Soil Symbol	Soil Name	Taxonomic Classification	Parent Material	Texture		Drainage Class	% of Land Area	Acidification* Sensitivity Subcategory
				Upper Horizons	Lower Horizons			
HD	Hilda	(Organic) Humisol	Moderately thick humic fen peat with layers of mesic fen peat over silty to sandy sediments			Poorly to very poorly drained	<0.1	3.1
JVI	Jarvie	Humic Eluviated Gleysol	Coarse-loamy, weakly calcareous lacustrine material	Loam and silt loam	Loam and silt loam	Poorly drained	0.4	3.1
JFF	Jeffrey	Gleyed Eluviated Black Chernozemic	Fine-silty, moderately to strongly calcareous lacustrine material	Loam and silt loam	Silt loam	Imperfectly drained	<0.1	3.2
KHW	Kehiwin	Orthic Dark Gray Chernozemic	Fine-loamy, moderately to strongly calcareous glacial till	Loam	Clay loam	Well drained	4.5	3.2
LCY	LaCorey	Orthic Gray Luvisol	Fine-laomy, moderately to strongly calcareous glacial till	Loam	Clay loam	Moderately well drained	24.9	2.1
LFN	LaFond	Orthic Black Chernozemic	Fine-loamy, moderately to strongly calcareous glacial till	Loam	Clay loam	Well drained	0.1	3.2
LVT	Lavesta	Orthic Gray Luvisol	30 to 75 cm fine-silty material over fine-loamy weakly calcareous glacial till	Loam, silt loam	Silty clay loam, clay loam	Moderately well drained	***	2.1
LIZ	Liza	Eluviated Eutric Brunisol	Sandy alluvium or aeolian material	Loamy sand	Loamy sand	Rapidly drained	0.3	1.1
ML	Maloy	(Organic) Mesisol	Thick mesic fen peat			Poorly to very poorly drained	0.7	3.1
MN	Manatokan	(Organic) Mesisol	Thin fibric peat over moderately thick to thick mesic fen or forest fen peat over loamy glacial till or sandy to silty sediments			Poorly to very poorly drained	4.1	3.1

continued...

Table 5. Continued.

Soil Symbol	Soil Name	Taxonomic Classification	Parent Material	Texture		Drainage Class	% of Land Area	Acidification* Sensitivity Subcategory
				Upper Horizons	Lower Horizons			
MPV	Mapova	Humic Eluviated Gleysol	Fine-loamy, weakly calcareous glacial till	Loam	Clay loam	Poorly drained	1.7	3.1
MYW	Maywood	Orthic Gray Luvisol	Fine-clayey, lacustrine material	Clay loam and silty clay loam	Silty clay	Moderately well drained	0.1	2.1
NTW	Nestow	Eluviated Dystric Brunisol	Sandy alluvium or aeolian material	Loamy sand	Loamy sand or sand	Rapidly drained	2.5	1.1
NWO	Newbrook	Low Humic Eluviated Gleysol	Fine-loamy, weakly calcareous glacial till	Loam	Clay loam	Poorly drained	1.9	3.1
NIT	Nicot	Eluviated Eutric Brunisol, Brunisolic Gray Luvisol	Sandy alluvium or aeolian material	Loamy sand	Loamy sand and sandy loam	Rapidly drained	4.1	1.1
POK	Ponoka	Eluviated Black Chernozemic	Fine-silty, moderately to strongly calcareous lacustrine material	Loam and silt loam	Silty clay	Well drained	0.4	3.2
RB	Rough Broken Land	Undifferentiated	Glacial till, colluvium glaciofluvial material	Undifferentiated		Variable	1.7	3.3
RDW	Redwater	Orthic Dark Gray Chernozemic	Sandy, weakly calcareous alluvium or aeolian material	Sandy loam and loamy sand	Sandy loam and loamy sand	Well to rapidly drained	0.1	2.1
RMY	Rimbey	Orthic Dark Gray Chernozemic	Fine-silty, moderately to strongly calcareous lacustrine material	Loam and silt loam	Silty clay loam	Well drained	0.1	3.1
SDN	Spedden	Dark Gray Luvisol	Fine-loamy, moderately to strongly calcareous glacial till	Loam	Clay loam	Moderately well drained	7.1	2.2
SB	Stebbing	(Organic) Fibrisol	Thick sphagnum moss peat			Poorly to very poorly drained	0.3	2.3
SL	St. Lina	(Organic) Mesisol	Moderately thick fen or forest fen peat over loamy glacial till			Poorly to very poorly drained	1.5	3.1

continued...

Table 5. Concluded.

Soil Symbol	Soil Name	Taxonomic Classification	Parent Material	Texture		Drainage Class	% of Land Area	Acidification* Sensitivity Subcategory
				Upper Horizons	Lower Horizons			
TWI	Tawatinaw	Orthic Gray Luvisol	Loamy-skeletal, weakly calcareous glacial till	Sandy loam	Sandy loam sandy clay loam	Well drained	0.2	1.2
TOM	Tolman	Orthic Gray Luvisol	Fine-loamy, moderately to strongly calcareous lacustrine material	Loam and silty loam	Silty clay loam, loam, silt loam	Well drained	1.0	2.1
TM	Tompkins	(Organic) Fibrisol	Moderately thick fibric sphagnum moss peat with humic fen peat layers over loamy glacial till or silty sediments			Poorly to very poorly drained	0.3	2.3
TMN	Tomson	Orthic Gray Luvisol	Fine-loamy, moderately to strongly calcareous glacial till overlain by thin (<30 cm) sandy material	Loamy sand sandy loam	Sandy clay loam	Moderately well drained	4.7	1.2
TR	Tucker	(Organic) Fibrisol	Moderately thick sphagnum moss peat with layers of mesic forest peat and humic fen peat over silty or sandy sediments			Poorly to very poorly drained	3.2	2.3
VIL	Vilna	Gleyed Eluviated Black Chernozemic	Fine-loamy, moderately to strongly calcareous glacial till	Loam	Loam, sandy clay loam	Imperfectly drained	0.1	3.2
WST	Winston	Dark Gray Luvisol	Fine-clayey, weakly calcareous glacial till	Loam, silt loam	Clay	Moderately well drained	0.3	2.2
WTB	Winterburn	Orthic Dark Gray Chernozemic	Fine-silty, weakly calcareous pitted deltaic material	Loam	Silt loam	Well drained	<0.1	3.2

* Subcategories of sensitivity to acidification. Defined in later section in the report.

** Moderately thick peat refers to peat that is more than 60 cm but less than 130 cm thick. Thick peat refers to peat that has a thickness of 130 cm or greater.

*** Not shown on map as a separate unit.

soil series, series complex, and land types with sensitivity subcategory classification is given in Appendix B.

Data regarding the physical and chemical properties of nearly all of the soil series or series complexes are given in the two soil survey reports cited earlier. To provide some measure in this report of the ranges and vertical distributions of these properties, pertinent data for profiles of soil series or series complexes selected from each of the subgroups or great groups are presented in Tables 2 and 3 for mineral and organic soils respectively. These data indicate several salient qualities in each of the subgroups that affect their sensitivity.

1. The soils of the Chernozemic subgroups, in relation to other mineral soils, have a thick Ah horizon with a high organic matter content and high CEC. In reaction (pH) the Chernozemic soils are predominantly slightly acid or neutral throughout the profile.
2. The soils of the Orthic Gray Luvisols characteristically have a low organic matter content and relatively low CEC in the A horizons as compared to the B horizons. In the B horizons the organic matter is low but the CEC is markedly higher than in the A horizons because of pronounced increase in clay content. Usually the upper part of the B horizon has the lowest pH value in the profile.
3. The Dark Gray Luvisol soils resemble those of the Orthic Gray Luvisol subgroup. They do, however, have a moderately thick upper horizon (Ah) that contains appreciably more organic matter and hence has a markedly higher CEC.
4. The soils in the Brunisolic subgroup in this area are largely sandy throughout the profile and consequently have low clay contents. Their organic matter contents are also low. Therefore because of

their low clay and organic matter contents the CEC is low. Other characteristics of these soils attributable to their sandy texture are rapid permeability and low or very low moisture holding capacity.

5. There are several subgroups of Gleysolic soils but their organic matter content, CEC and pattern of pH with depth are comparable to the data for the Mapova series shown in Table 2. In general they have surface horizons with medium to high contents of organic matter and relatively high CEC in surface and subsurface horizons. They are generally slightly acid to neutral in reaction throughout the profile.
6. Table 3 displays data for the chemical properties of selected profiles of organic soils. These data show that the soils of the Fibrisol subgroups are extremely acid while the Mesisols and Humisols range from medium to slightly acid. Some of the Humisol soils mapped are mildly alkaline.
7. In general the combined thickness of A and B horizons ranges from about 50 cm to about 100 cm in mineral soils.
8. A summarization of all the available data on exchangeable bases has shown that Ca and Mg combined constitute about 90% of the sum of exchangeable bases.
9. Nearly all of the mineral soils, even those that are strongly acid in the B horizons, have a relatively high percent base saturation; 75 to 80% or even higher.
10. Some deeper percolation may result in leaching of bases mobilized by acidification in the more pervious

soils. The more or less ubiquitous occurrence of the Cca horizon (the horizon of lime accumulation) in the lower part of the soil profiles implies however, that deeper percolation in many of these soils has been minimal.

6. SENSITIVITY CLASSIFICATION OF SOILS OF THE SAND RIVER AREA

6.1 OBJECTIVES

The project had two objectives. The first objective was to develop criteria whereby soil survey information and associated laboratory-derived data could be used to classify the soils of the province into the following three broad categories of sensitivity:

Category 1 - Most sensitive soils

Category 2 - Soils of intermediate sensitivity

Category 3 - Least sensitive soils

The second objective was to develop procedures so that a soil survey of an area could be used to prepare a map to show the distribution of soils in the area according to their sensitivity.

6.2 SOIL SURVEY INFORMATION AND DATA AVAILABLE

The Sand River soil survey report (Sand River Area 1975) includes; descriptions and discussions of each of the 50 soil series, series complexes and land types that occur in the area, tables of laboratory-derived data on the physical and chemical properties of each of the soils, and a soils map on a scale of 1:126 720. The descriptions and discussions provide information on the morphological characteristics and physical properties and such other attributes as moisture holding capacity, perviousness and moisture regime of each kind of soil. This information is summarized in Table 5.

The laboratory-derived data for each soil by horizons, include particle size distributions, organic matter content, pH measured in soil-water paste, CEC, exchangeable bases and total acidity measured at pH 7.0. The analytical methods are listed in the Sand River Soil Survey Report but some comments are included here on the procedures that were followed for measuring CEC. The CEC values for the Sand River soils were obtained by summing the

exchangeable bases (Ca, Mg, K, and Na) extracted with 1N ammonium acetate solution buffered at pH 7.0 and the total soil acidity measured separately at pH 7.0. Some similar soils from the Fort McMurray area (Turchenek and Lindsay 1981) were included in the data analysis. The CEC of these soils was determined by measuring the quantity of exchangeable NH_4 that was adsorbed by the soil after extraction of exchangeable bases with an ammonium acetate solution. The carbonate content expressed as $CaCO_3$ equivalent was determined for calcareous horizons. Mineralogy of the soils was provided by a study of the mineralogy conducted on five soil profiles in the area by Abder-Ruhman (1980).

6.3 RATIONALE FOR CLASSIFICATION OF SOIL SENSITIVITY

6.3.1 Criteria

It was indicated in an earlier section of this report that BFC was the major factor determining soil sensitivity. It was also indicated that the magnitude of BFC is affected by the pH of the soil and in evaluating soil sensitivity the effects of other factors such as soil perviousness, moisture holding capacity, natural drainage class and mineralogy should be considered. The dominant role of BFC and the significance of the other factors served as the basis for the criteria developed for soil sensitivity classification. Because CEC could serve as an index of BFC and a considerable quantity of CEC data were available on Sand River soils this parameter was used for estimating BFC.

A more or less subjective approach was followed to establish the criteria for defining the three major categories of soil sensitivity. The various mineral soils for which particle size distribution and CEC data were available were segregated by subgroups and then arranged in sequential order according to the magnitude of CEC values. This comparison revealed that coarse textured (sands, loamy sands and sandy loams) soil horizons

having a low organic matter content (2% or less) had CEC values that were less than 5 or 6 meq/100 g of soil. Fine textured soils or medium textured soils with a high organic matter content (5% or higher) had CEC values in the upper teens or higher. The CEC values in the intermediate range were found mostly in soils of medium texture and medium or low organic matter content. The conclusion that has been drawn from pertinent literature from various sources is that sandy soils, unless they are calcareous, are readily sensitive to acidification because of their low BFC. Similarly, fine textured soils were considered, as a rule, to have high BFC (Wiklander 1980). In view of this information the ranges of CEC values chosen at that time as indicators of low, medium and high BFC categories were respectively: <5 meq, 5 to 15 meq, and >15 meq/100 g of soil. It was learned subsequently that McFee (1980) had employed nearly analogous CEC values of <6.2 meq, 6.2 to 15.4 meq, and >15.4 meq/100 g of soil as criteria for defining categories of sensitivity. Because of the latter additional information the CEC ranges for defining BFC categories were revised slightly as follows:

Low BFC - CEC 6 meq or less
Medium BFC - CEC 6 to 15 meq
High BFC - CEC more than 15 meq

Similar ranges in CEC are implied in subsequent discussion where references are made to relative magnitude of CEC in describing soils. Frequent references are also made to levels of organic matter content. The following ranges in percent organic matter are implied:

Low organic matter content - less than 2%
Medium organic matter content - 2 to 5%
High organic matter content - over 5%

6.3.1.1 .CEC-pH relationship. CEC has been defined as the sum of exchangeable cations, expressed in milliequivalents, that 100 g of soil can adsorb .(Soil. Sci. Soc. Amer. 1973). The magnitude of CEC is dependent on the extent of the total negative change of the soil, some of which is constant charge and some variable (i.e., it is pH-dependent). Mehlich (1981) identified the CEC associated with each of these negative charge designations as CECt, CECc and CECv. The source of negative charge in the soil is the clay fraction, the silt fraction to some extent, and the organic matter. They differ considerably however in the relative extent of total negative charge they exhibit when expressed on a per unit weight basis and in the proportion of constant to variable charge they contribute. The clay minerals such as those that prevail in Sand River soils (Table 4) constitute the source of constant negative charge in these soils and thus of their CECc. These clay minerals however, acquire a small proportion of variable charge above a soil pH of about 5.2 to 5.5 (Bohn et al. 1979, pp. 94-99). The negative charge of organic matter is variable and on a per unit weight basis, is of considerably greater magnitude than that associated with clay minerals as indicated by the CEC-pH relationship depicted in Figure 2. It is apparent that in the medium acid to neutral reaction range, actually above about pH 5.2, the CEC is due largely, if not entirely, to a variable negative charge. In the more acid reaction range, that is below a pH of about 5.5 to 5.2, the CEC in mineral soils is due primarily to a constant negative charge although the organic matter fraction will contribute some variable charge.

Bache (1976) stressed the need to appreciate the possible influence variable charge may have on soil CEC when this parameter is used to interpret some aspects of soil behaviour. He also stressed the need to recognize that measured values of soil CEC are dependent on the method used in their determination. As an example Dolman and Buol (1967) determined the CEC of an extremely

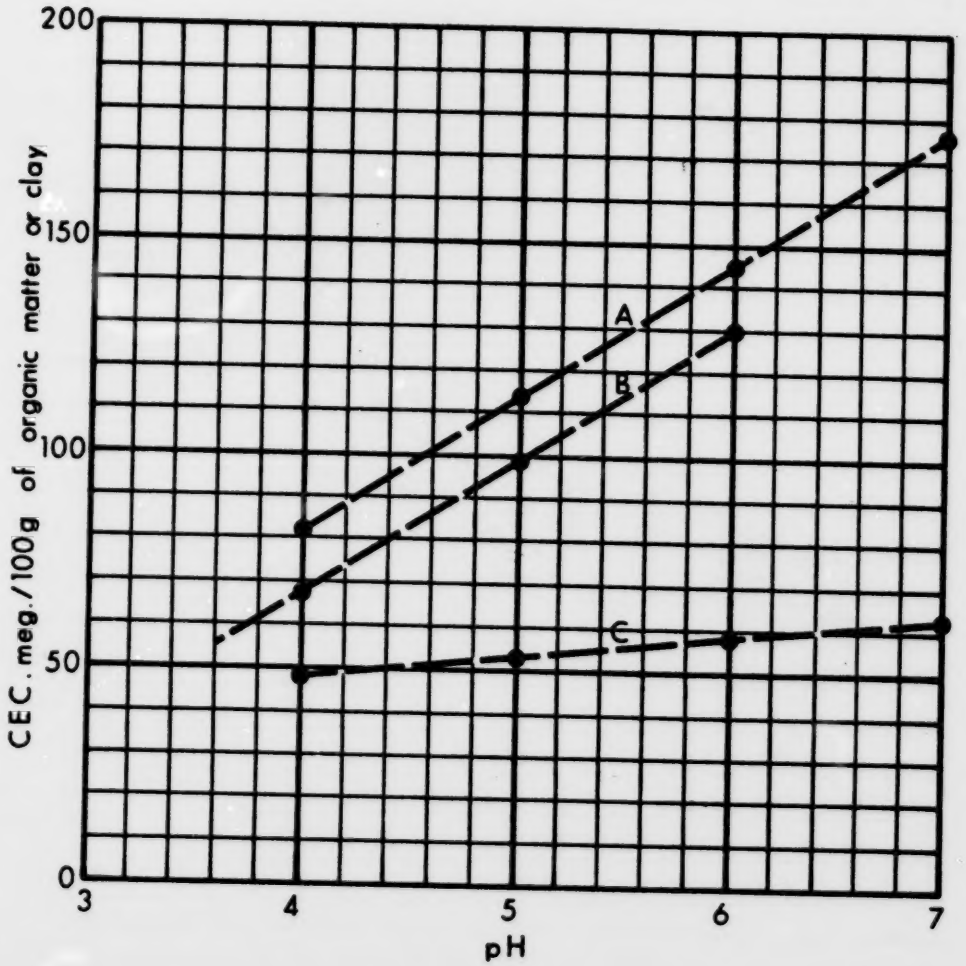

Figure 2. Reduction in CEC of organic matter and clay with decrease in soil pH.

A - Organic matter fraction in Ap horizons (Helling et al. 1964)
B - Humus of forest soils (Kalisz and Stone 1980)
C - Clay fraction in Ap horizons (Helling et al. 1964)

acid organic soil by two methods, one determination was made at pH of the soil and the other at pH 7.0. They obtained CEC values of 15.3 and 97.3 meq/100 g of soil respectively. Most of the soils of the Sand River area are medium acid to neutral in reaction. A number of them are organic or are mineral soils that have an appreciable content of organic matter in the surface horizons. The CECv in such soils is likely to be considerable and since the CEC measurements were made at pH 7.0 the CECt is likely to be dominated by CECv.

6.3.1.2 BFC-pH relationships. It has been previously mentioned that medium acid to neutral soils would be expected to exhibit lower BFC than would be found in strongly to very strongly acid soils with similar CEC values. The BFC-soil pH relationship is indicated in Figure 3 which shows the plots of pH of soils from near neutrality to extremely acid reaction against incremental increase in total soil acidity as represented by decreasing percent base saturation. The percent base saturation is an inverse index of soil acidity expressed as percent of CEC, that is an increment of decrease in base saturation represents a corresponding increase in soil acidity. The curves in Figure 3 show plots of the pH and base saturation data available for samples of the Ae and AB-Bt horizons of 65 profiles of Orthic Gray Luvisolic soils from the Sand River, Tawatinaw and Fort McMurray regions. Practically all of the very strongly or extremely acid samples came from the latter area. Plots of these two horizons are given since the Ae horizon, singly, or with varying proportions of the AB-Bt horizons, constitutes the mineral topsoil in these soils to a depth of 18 cm. The wider 90% confidence limits for some of the mean values of pH were generally found in the base saturation intervals for which only a few data were available. A review of the organic matter content-clay content ratios in each of the two horizons indicated that they differed markedly in this

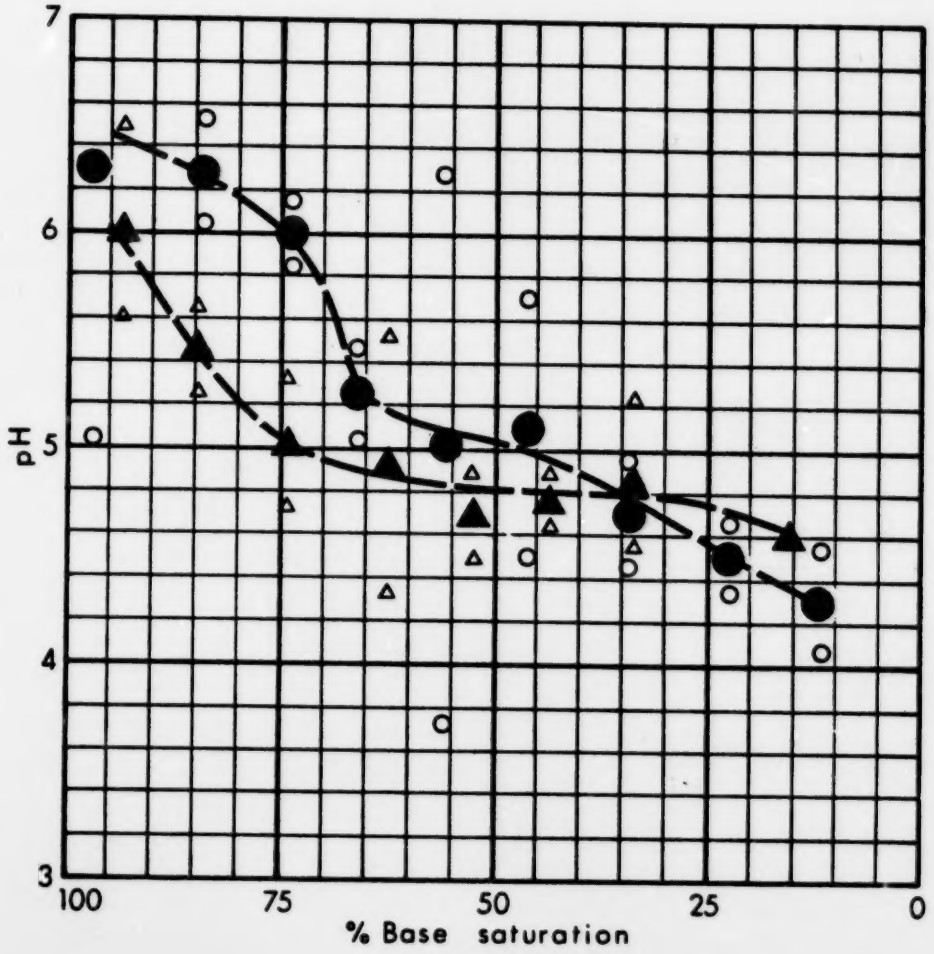

Figure 3. Relationship between pH (H_2O) and NH_4OAC base saturation by 10% intervals in Ae and AB-Bt horizons of Orthic Gray Luvisolic soils.

● pH mean ○ 90% confidence interval Ae horizon

▲ pH mean △ 90% confidence interval AB-Bt horizon

N = 65

property. These ratios, although they varied widely from profile to profile, had average values of 0.24 and 0.04 for the Ae and the AB-Bt horizons respectively. On the basis of these ratios it was concluded that the variable charge CEC constituted a higher proportion of the total CEC of the Ae than of the AB-Bt horizon, especially in the medium acid to neutral reaction range.

An examination of the plotted curves in Figure 3 indicated that the soil reaction between pH 5.2 to about 5.5 divides the soils that were examined into two categories depending on their BFC in relation to soil pH. The relative rate of decrease in soil pH, is indicated by the steepness of the slope of curve segments in response to given increasing increments of acidity. The rate of pH decrease in the soils with a pH 5.2 to 5.5 and above is considerably higher than the rate for the soils in the reaction range of pH 5.2 to about 4.3. A visual estimate of the average steepness of the slope above and below a pH of 5.2 indicated a relative rate of pH decrease of about 3 to 1 for the Ae horizon and 5 to 1 for the AB-Bt horizons. The more rapid rate of pH decrease in this range is of particular significance from an agromonic standpoint. It was pointed out by Hoyt and Nyborg (1971) that a small decrease in soil pH in the medium to slightly acid range may increase soluble aluminum to levels that are toxic to some crop species. Comparable trends in relative rate of pH change were apparent in the data reported by Linzon and Temple (1980) based of their observations near Parry Sound, Ontario. They obtained pH data on field soils before and after 18 years of exposure to acidic depositions. No apparent change in pH was found in the very strongly acid soils. The average pH of the upper horizon of these soils was about 4.8 before and after exposure to the depositions. In comparison, the pH of a medium acid soil decreased from 5.7 to 4.8.

The definition of BFC has been given as the amount of acid required to decrease the pH of a given quantity of soil by

one pH unit. In more expedient terms BFC is inversely related to the magnitude of pH decrease in response to a given increase in soil acidity. The relationship depicted in Figure 3 shows that in similar soils, the BFC on a relative basis is appreciably lower in the medium acid to neutral reaction range than it is in the reaction range below pH 5.2. Furthermore, since soil sensitivity and BFC are inversely related the sensitivity of the medium acid to neutral soils is correspondingly greater than that of the more acid soils. This relationship of BFC to soil reaction is pertinent to the soils of the Sand River area. McFee (1980) and Wiklander (1979) considered slightly acid soils with low BFC as particularly sensitive to acidification.

Bache (1980a), Wiklander and Andersson (1972) and Wiklander (1980) indicated that exchangeable bases, especially Ca, are replaced more readily by H^+ in the medium acid to neutral reaction range; the reaction range where variable charge CEC prevails. Wiklander and Andersson (1972) attributed this to the high cation exchange efficiency of H^+ in this range of pH. He also indicated that in the very strongly to strongly acid reaction range the efficiency of H^+ is considerably lower so a smaller proportion of what exchangeable bases may be present are replaced. The BFC in this reaction range is more pronounced in mineral soils since the rate of decrease in pH is more subdued. This is evident in Figure 3, especially in the case of the AB-Bt horizon which, compared to the Ae horizon, has a much lower organic matter-clay content ratio. In this reaction range CEC is determined by constant negative charge except for that proportion of the variable change contributed by the organic fraction as suggested by the slightly steeper gradient of the Ae horizon curve. The effects of increased acidification in such soils will be reflected more in a decrease in base saturation than in the associated modest decrease in pH. The buffering property in the very strongly acid soils is likely to be better expressed by the quantity of exchangeable bases present as proposed by Wang and Coote (1980).

Apparently the BFC as defined, can be inferred effectively from the BFC-pH relationship in soils with a pH of 5.2 or higher but less effectively in more acid soils. It is also postulated that the effectiveness of this method for the medium acid to neutral soils can be improved if the pH-dependent proportion of CEC were known. The difference between CEC values determined at pH 5.2 to 5.5 and at pH 7.0 may provide an approximation. It is recommended that the method reported by Pratt (1961) or other appropriate procedures be explored for this purpose.

6.3.2 Guidelines for Organizing Criteria for Sensitivity Classification of Soils

The following guidelines were followed for using criteria to classify individual soils into the broad categories and the subcategories of sensitivity:

1. The sensitivity of a soil is largely determined by its BFC and it constitutes the major criterion for characterizing the three broad categories.
2. The BFC of soils is related to soil pH, hence this parameter should be considered an important property in defining subcategories.
3. The upper horizons represent the portion of the soil profile that are most directly affected by surficial additions of anthropogenic acidity. Therefore the evaluation of the sensitivity of a soil should be based primarily on the sensitivity of the horizons that constitute the topsoil in mineral soils. A Thickness of 18 cm was assumed for the topsoil.
4. The BFC, sensitivity-pertinent properties, and attributes of the subsurface horizons are expected to influence the sensitivity of the soil and should be considered in defining subcategories. Arbitrary depths of 18 to 50 cm and in some soils to 100 cm

were adopted as the depths to which the subsurface horizons would be characterized.

5. The prevalence and quality of subsurface water are important factors in determining the sensitivity of poorly and very poorly drained soils and should be so recognized in the definitions of appropriate subcategories.

6.3.3 Soil Sensitivity Subcategories

Fifty kinds of soils consisting of 38 soil series or series complexes, two land types of mineral soils and 10 series complexes of organic soils were identified and mapped in the area.

This wide array of soils emphasized the need for a scheme and criteria for assembling the soils into groups that would simultaneously facilitate the following:

1. Classification of the soils within a group into an appropriate category of sensitivity.
2. Discussion of the pertinent properties and behaviour of soils in response to acidification.
3. Development of mapping units for showing the areal distribution of soils according to their sensitivity.

To meet this need, the soils identified and mapped in the soil survey were assembled into eight groups, referred to in this report as subcategories, based on similarities in sensitivity-pertinent properties and attributes of the soils according to the guidelines presented previously. It should be recognized that the term, subcategory, as used in this report refers to soils assembled according to their similarity in sensitivity-pertinent properties and attributes. It does not represent a heirarchical subdivision of a broad category in the sensitivity classification of soils. An outline of the eight subcategories is given in the section following.

6.3.4 Outline of Sensitivity Classification Scheme for Sand River Soils

This outline presents the scheme that was developed to classify the soils of the Sand River area as to their sensitivity. Two digit symbols were used to identify the broad categories of relative sensitivity and the component subcategories, the first digit denoting the category and the second digit the subcategory.

1. Soils most sensitive to acidification
   - 1.1 Slightly to medium acid soils with low BFC throughout the soil profile.
   - 1.2 Slightly to medium acid soils with low BFC in upper horizons and medium BFC in lower horizons.
2. Soils of intermediate sensitivity to acidification.
   - 2.1 Slightly to medium acid soils with medium BFC in upper horizons and medium to high BFC in the subsoil.
   - 2.2 Slightly to medium acid soils with medium to high BFC in the upper horizons and high BFC in the subsoil.
   - 2.3 Very strongly to extremely acid, very poorly drained organic soils.
3. Soils least sensitive to acidification.
   - 3.1 Medium acid to mildly alkaline poorly to very poorly drained mineral and organic soils.
   - 3.2 Slightly acid to neutral soils with high BFC.
   - 3.3 Soils on relatively recent or slightly altered parent materials.

6.4 PROCEDURE FOR DETERMINING SENSITIVITY CLASSIFICATION OF SOILS

The placement of each soil series or series complexes into a category and subsequently into a subcategory depending on

its relative sensitivity to acidification was based on the depth distribution of pertinent physical and chemical properties and on those attributes that may affect its sensitivity. The properties that were considered sensitivity-pertinent are those that determine BFC, (viz CEC, and pH), and those that control the retention and transmission of water (viz. moisture holding capacity and perviousness). The attributes of the soils such as the natural soil drainage class and the possible inflow of mineral charged water were also considered. The natural soil drainage class refers to the rapidity and extent of the internal removal of water from soils in relation to addition, both by incident precipitation and runoff, and by inflow from surface, subsurface or groundwater sources. The significance of the latter attributes, moisture holding capacity and perviousness are discussed when the sensitivity of specific subcategories are considered. The role of soil mineralogy was considered in a qualitative fashion. It is surmised that weathering of soil minerals, especially those that are more weatherable, will not only abet buffering but will replenish some of the exchangeable bases mobilized by acidification. Mineral species contents data for the fine earth fraction of till-derived soils in the Sand River area (Table 4) indicate an appreciable content of plagioclase and trioctahedral mica and some amphibole minerals exists. These minerals are considered less resistant to weathering and should exert a progressively moderating effect as pH decreases.

The properties and attributes of each series or series complex is found in the soil survey report and also summarized in Table 5. Some of the laboratory-derived data are also included. A considerable quantity of information on these soils is presented in other soil survey reports, technical articles, M.Sc. thesis or is on file at the Alberta Research Council.

6.4.1 Summarization and Organization of Chemical Data

All of the pertinent chemical data, such as data on CEC, exchangeable bases and pH, were extracted from the several sources and organized into a suitable format as shown in Table 6. The data on CEC and exchangeable bases, originally expressed on a weight basis, were converted to a volume and area basis as explained in Appendix A. In Table 6 the data are given for arbitrary soil depth intervals of 0 to 5 cm, 5 to 18 cm, 18 to 50 cm and in some cases 50 to 100 cm/m^2. This approach facilitated expressing the gross CEC/m^2 and consequently the gross BFC/m^2 to depths that were considered pertinent. The 0 to 5 cm interval comprises the surficial layer of soil that would be subjected to the direct impact of surficial additions of acidity-generating materials. This layer and the 5 to 18 cm depth would approximate the plow layer, while the 18 to 50 cm interval would include all or a considerable portion of the subsoil. Where data for more than one profile of a soil series or series complex were available, the data were combined and are shown as means and ranges of values. Weighted horizon thickness and bulk density values were used to convert the original data, expressed on a weight basis, into equivalent units of area and selected depth. How these converted data relate to the CEC values for the low, medium and high BFC is explained in Table 7. The values for CEC and the sum of exchangeable bases presented in the Table 6 format were rounded off to whole numbers where the values were 10 or greater. These converted data as shown in Table 6 were prepared for each of the soil series or series complexes but only the data for one or two selected series or series complexes from each taxonomic subgroup or great group are shown. Comparable data for the remaining soils, compiled in a similar tabular form, are on file at the Alberta Research Council and are available on request.

Table 6. Data for cation exchange properties and pH summarized by depth intervals to 50 or 100 cm for soils of selected series or series complexes. Values for cation exchange properties expressed in E (1000 meq) per square meter (Em^2).

Depth Intervals	0-5 cm		5-18 cm		18-50 cm		50-100 cm	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
FRY Fergy Series 2 profiles - Black Chernozemics								
pH	6.8	6.8-6.9	6.8	6.8-6.9	6.4	6.1-6.7		
E Bases E/M2	14	13-15	37	35-38	67	58-76		
CEC E/M2	15	15-15	40	40-40	73	63-83		
Base Sat. %	92	87-97	92	87-97	92	92-92		
CEC meq/100g	28	28-28	28	28-28	16	14-18		
KHW Kehiwin Series 2 profiles - Orthic Dark Gray Chernozemics								
pH	6.4	5.7-7.1	6.3	5.6-7.1	6.1	5.4-6.8		
E Bases E/M2	11	9-14	29	21-37	72	62-82		
CEC E/M2	13	12-14	33	30-37	83	81-85		
Base Sat. %	85	70-100	85	69-100	85	77-96		
CEC meq/100g	24	23-26	23	20-26	19	18-19		
ABC Athabasca Series 8 profiles - Orthic Gray Luvisols								
pH	6.1	5.2-6.6	5.9	5.0-6.6	5.4	5.0-6.0		
E Bases E/M2	2.7	2.2-4.6	11.4	6.2-18	70	59-86		
CEC E/M2	3.5	2.7-5.1	14.6	8.7-23	79	68-100		
Base Sat. %	75	59-90	80	71-92	70	59-87		
CEC meq/100g	5.4	4.2-7.8	8.3	5.0-13	17	14-21		
LCY LaCorey Series 2 profiles - Orthic Gray Luvisol								
pH	6.3	6.0-6.6	6.0	5.5-6.4	5.3	5.0-5.6		
E Bases E/M2	3.9	3.8-4.0	15	13-17	75	64-86		
CEC E/M2	4.8	4.6-5.0	18	15-21	85	76-94		
Base Sat. %	81	76-87	85	82-88	88	84-91		
CEC meq/100g	7.4	7.1-7.7	10	8.7-12	18	16-20		
TMN Tomson Series 4 profiles - Orthic Gray Luvisols								
pH	6.0	4.6-6.9	6.3	5.1-6.8	5.8	5.0-6.3		
E Bases E/M2	1.7	0.4-3.5	5.1	1.8-13	49	38-60		
CEC E/M2	2.8	1.8-4.2	6.7	3.8-14	60	49-74		
Base Sat. %	60	25-83	67	34-89	82	74-89		
CEC meq/100g	4.3	2.5-6.5	3.8	2.3-7.9	13	10-16		
GMT Grosmont Series 1 profile - Dark Gray Luvisol								
pH	5.8		5.3		4.7			
E Bases E/M2	9.4		23		85			
CEC E/M2	12		31		114			
Base Sat. %	77		76		75			
CEC meq/100g	24		18		24			

continued...

Table 6. Concluded.

NIT Nicot Soil 2 profiles - Eluviated Eutric Brunisols								
pH	6.2	6.2-6.3	6.3	6.3-6.3	6.3	6.3-6.3	6.4	6.4-6.5
E Bases E/M2	1.3	0.9-1.7	3.2	2.6-3.8	10	8.5-12	14	12-16
CEC E/M2	1.9	1.3-2.5	4.9	3.8-6.0	14	12-15	17	14-20
Base Sat. %	69	68-70	65	63-67	75	70-80	85	85-85
CEC meq/100g	2.7	1.8-3.6	2.6	2.0-3.2	2.0	2.5-3.2	2.2	1.9-2.6
MPV Mapova Series 1 profile - Humic Eluviated Gleysol								
pH	6.6		6.8		6.6			
E Bases E/M2	11		20		82			
CEC E/M2	12		22		85			
Base Sat. %	94		91		96			
CEC Meq/100 g	21		14		18			
BL Birkland Complex 1 profile - Fibrisols								
pH	3.4		3.4		3.4		3.6	
E Bases E/M2	0.8		2.1		5.1		27	
CEC E/M squared	6.6		17		42		131	
Base Sat. %	12		12		12		20	
CEC meq/100 g	131		131		131		163	
SL St. Lina Complex 5 profiles - Mesisols								
pH	5.9	5.5-6.2	5.9	5.5-6.4	6.0	5.6-6.5	5.8	5.4-6.3
E Bases E/M2	10	1.9-18	26	5.0-44	64	53-85	83	60-116
CEC E/M2	13	5.3-22	33	14-54	82	62-109	113	99-142
Base Sat. %	77	36-92	76	36-92	78	64-92	73	58-87
CEC meq/100 g	115	97-146	113	97-139	114	97-134	106	83-138
BN Bonnie Complex 1 profile - Humisols								
pH	5.6		5.7		5.8		5.8	
E Bases E/M2	11		25		44		99	
CEC E/M2	18		40		70		152	
Base Sat. %	61		62		63		65	
CEC meq/100 g	123		119		110		112	

Table 7. Gross CEC in E/m^2 for upper and lower limits of BFC in the sensitivity categories for mineral soils.

Category	CEC in meq/100 g soil	CEC in E/M2 by depth intervals** 0-5 cm	5-18 cm	18-50 cm	50-100 cm
1. Low BFC	<6	<3.5	<10	<28	<43
2. Medium BFC	6-15	3.5-9	10-25	28-70	43-108
3. High BFC	>15	>9	>25	>70	>108

* Bulk density 1.3 in the 0 to 18 cm depth, 1.5 in the 18 to 100 cm depth range.

** These ranges of values in E/m^2 indicate the gross BFC of soil in each depth interval.

CEC values expressed in meq/100 g soil are included in Tables 6 and 7 to show the relationship between the gross CEC given in E/m^2 and the CEC on a weight basis.

A summary of the pH of soils from the Sand River area obtained by the Alberta Agriculture Soil and Feed Testing Laboratory (Dept. Ag. Soil Br. 1980) is given in Appendix C.

6.4.2 Sensitivity Classification of Soil Series and Series Complexes

The soil series and series complexes as shown below, were classified into categories and subcategories of sensitivity according to the sensitivity classification scheme outlined in an earlier section. The BFC of the soils by depth intervals (Table 6) constituted the main criterion for classifying the soil series and series complexes into the broad categories of relative sensitivity. Additional criteria such as soil pH and the other sensitivity-pertinent properties and attributes served as the basis for placing the soil series and series complexes into subcategories. The sensitivity-perintent properties and attributes of the soils placed in each of the subcategories are described briefly below and some comments are made regarding the anticipated behaviour in response to acidification. The soil series and series complexes included in each of the subcategories are identified by their soil survey map symbols consisting of 2 or 3 capital letters.

6.4.2.1 Soils most sensitive to acidification.

6.4.2.1.1 Slightly to medium acid soils with low BFC throughout the soil profile, subcategory 1.1. These soils are deep, sandy, and rapidly pervious, and have a low organic matter content, CEC, and low or very low moisture holding capacity. They are susceptible to rapid percolation when subjected to additions of excessive moisture. In such instances they could readily translocate

materials in solution to lower horizons or even to groundwater. There is a possibility however that under conditions conducive to rapid percolation, only minimal cation exchange equilibration may occur at the percolating water-soil interface. In such cases the surficial acidity inputs in solution may be little affected by passage of the percolating water through the soil. Because of their low BFC, low CEC and slightly to medium acid reaction (pH) range the soils are generally expected to respond readily to inputs of acidity both in lowering of pH and in accelerated mobilization of exchangeable bases. In instances of appreciable percolation these mobilized bases will be susceptible to translocation to greater depths or even to groundwater.

This subcategory includes the following soil series or series complexes:

Amisk (AMK)
Clouston (CUN)
Edwand (EDW)
Liza (LIZ)
Nestow (NTW)
Nicot (NIT)

6.4.2.1.2 Slightly to medium acid soils with low BFC in the upper horizons and medium BFC in the lower horizons, subcategory 1.2. The upper horizons of these soils are sandy in texture, low in organic matter content and are rapidly pervious. They have a low CEC and moisture holding capacity. In contrast, the lower horizons are loamy or fine-loamy, only moderately pervious and have a medium CEC and moisture holding capacity. Because these soils are less pervious and retain more moisture in the lower horizons they are less favourable to deeper percolation and consequently transmission of water and solutions. Higher CEC and reduced perviousness in the lower horizons are also conducive to greater adsorption of the mobilized exchangeable bases. In response to surficial acidification

these soils will be readily susceptible to lowering of pH and mobilization of exchangeable bases in the upper horizons. The greater CEC and reduced perviousness of the lower horizons should appreciably minimize the loss of mobilized exchangeable bases from the soil profile. All of the following soils included in the subcategory have formed in coarse-loamy glacial till or materials that consisted of a relatively thin (<75 cm) sandy overlay on loamy or fine-loamy glacial till or lacustrine sediments:

Belloy (BLY)
Codesa (COA)
Gabriel (GBL)
Tawatinaw (TWI)
Tomson (TMN)

6.4.2.2 Soils with intermediate sensitivity to acidification.

6.4.2.2.1 Slightly to medium acid soils with a medium BFC in the upper horizons and a medium to high BFC in the subsoil, subcategory 2.1. This subcategory includes moderately to slowly pervious soils with a low organic matter content. They are loamy in the upper horizons and loamy or fine-loamy in the subsoil. Their CEC and moisture holding capacity are medium in the upper horizons and medium to high in the subsoil. In some of these soils, parts of the subsoil are strongly acid. Since the BFC is only medium and the reaction (pH) range is slightly to medium acid in the upper horizons, the pH will decline readily in response to surficial additions of acidifying materials. Of the exchangeable bases mobilized, some will be taken up by plants but most of those remaining will be translocated locally and adsorbed by the subsoil. It is surmised that only minimal amounts will be translocated to greater depths. It is anticipated that in these soils the response to acidification will result in more of a moderate rate of pH lowering rather than in a loss of exchangeable bases.

The soils of this subcategory are almost entirely of the Orthic Gray Luvisol subgroup, formed in loamy or fine-loamy parent material. Redwater, a coarse loamy Chernozemic soil was included in this subcategory because of its medium BFC in the upper horizons and subsoil. This soil however, is more pervious than the others.

The following are the soil series or series complexes included in this subcategory:

Athabasca (ABC)
Glory (GOY)
Good Ridge (GOG)
Grandin (GDI)
La Corey (LCY)
Maywood (MYW)
Redwater (RDW)
Tolman (TOM)

6.4.2.2.2 Slightly to medium acid soils with a medium to high BFC in the upper horizons and a high BFC in the subsoils, subcategory 2.2. The upper horizons of these soils are loamy with a medium content of organic matter. The subsoils are fine-loamy, fine-silty, or fine-clayey. These soils have a predominantly high CEC, are moderately to slowly pervious and have a medium to high moisture holding capacity. In some cases the subsoil is strongly acid. It is anticipated that in general the response of these soils to surficial additions of acidity will be similar to that of the 2.1 subcategory but the effects will develop at a somewhat slower rate because of the higher BFC of the upper horizons.

This subcategory is comprised of the following Dark Gray Luvisol soil series:

Fawcett (FWT)
Grosmont (GMT)
Spedden (SDN)
Winston (WST)

6.4.2.2.3 Very strongly to extremely acid organic soils, subcategory 2.3. This subcategory includes the poorly to very poorly drained but pervious, very acid, sphagnum-dominated organic soils found in the area. Because of their low bulk density and low pH these soils have a low effective CEC when considered on a volume rather than weight basis. It is surmised that surficial additions of acid generating materials also containing some salts such as Ca, Mg, Na, K and NH_4 will result in the following effects:

1. Because of their very acid nature the soils will adsorb little if any additional acidity from the transient waters affected by the surficial deposits. In fact the cations of the added salts may release some of the inherent exchangeable acidity and thus increase the acidity of the transient water and enrich the soil in exchangeable bases (i.e., increase its base saturation to some extent) (Wiklander 1975).
2. The progressive increase in acidity of the transient waters acquired by passage through these soils is likely to increase the acidity of effluent waters from this source. Boelter and Verry (1979) reported appreciable dissolved Al in effluent water from such sources.

The anticipated overall effect on these soils is that there will be little or no change in their acidity but the acidity of effluent water is likely to be increased. Thus these soils can be considered as having minimal sensitivity to acidification but indirectly they are likely to be conducive to an increase in the acidity of soil waters. Although this subcategory is placed in Category 2, serious thought was given to including it in Category 1 because of the effects that may result from the acid effluent from such soils (Clausen et al. 1980; Damman 1978).

This subcategory includes the following organic soil series complexes found in the area:

Birkland (BL)
Stebbing (SB)
Tompkins (TM)
Tucker (TR)

6.4.2.3 Soils least sensitive to acidification.

6.4.2.3.1 Medium acid to mildly alkaline, poorly to very poorly drained mineral and organic soils, subcategory 3.1. Included in this subcategory are the gleysolic soils and the Mesisol and Humisol organic soils. The gleysolic soils are slightly acid or neutral, have a medium to high BFC and CEC, and are predominantly moderately pervious. They are water-saturated for appreciable periods and commonly have a shallow water table. Since they occur in the lower landscape positions, some of these soils are subject to inundation by runoff. In some situations they receive subsurface inflows of groundwater.

The organic soils of this subcategory range from medium acid to mildly alkaline in reaction (pH) and have a medium effective CEC when considered on a volume rather than weight basis. Frequently however, these soils have a thin (generally <30 cm thick) layer of very strongly acid fibric material with properties similar to those of the subcategory 2.3 soils. These soils occur in areas of mixed fen-moss organic accumulation characteristically having shallow or very shallow water tables. These soils are also frequently affected to some degree by minerotrophic waters. The perviousness of these soils is variable but in general it is appreciably lower than that of the Fibrisols. Consequently the rate of soil water transmission is much slower. The effluent waters are expected to be much less acid than those from the 2.3 subcategory of soils.

The gleysolic soils are included in the least sensitive category because of their medium to high BFC and the possibility of ameliorating effects of minerotrophic waters from subsurface and runoff sources. Since these soils are slightly acid or neutral some depression of pH should be expected in the surface horizons from incident acidity. There should be little or no loss of exchangeable bases from these soils. According to their effective CEC, the BFC of the Mesisols and Humisols would be rated as medium. However because of the likelihood of compensating effects by the minerotrophic waters these soils are also placed in the least sensitive category. Considerable differences from area to area are to be expected. Where there is a thin surficial layer of the very acid fibric material, little or no change is expected in the surface horizon and transient water will not be altered as it percolates into the less acid soil beneath. Thus the lower horizons may be affected temporarily by the surficially added substances and may affect the effluent.

Following is a list of the soils of the area that were placed in this subcategory:

Gleysols

Codner (COD)
Daken (DKN)
Jarvie (JVI)
Mapova (MPV)
Newbrook (NWO)

Mesisols

Chatwin (CT)
Maloy (ML)
Manatokan (MN)
St. Lina (SL)

Humisols

Bonnie (BN)

Hilda (HD)

6.4.2.3.2 Slightly acid to neutral soils with a high BFC, subcategory 3.2. These soils have thick surface horizons with a high organic matter content, CEC, and base saturation. The subsoil likewise has a high CEC and base saturation but the organic matter content is low. Physically these soils are loams or silt loams in the surface horizons, and fine-loamy, fine-silty or fine-clayey in the subsoils. They are moderately to slowly pervious and have a medium to high moisture holding capacity. Because of the high BFC, especially in the surface horizons, acidity inputs to these soils should result in a relatively slow rate of pH lowering. However, the cation exchange efficiency of H^+ is high in the slightly acid to neutral reaction range so more exchangeable bases will be mobilized in these soils than for a comparable pH decline in other soils (Gasser 1973). Furthermore since the base saturation is high an appreciable proportion of the mobilized bases not recycled by plants may be translocated. Thus while changes in these soils will be slow because of their high BFC, advanced acidification may result in an appreciable change. The lowering of pH will also progressively reduce the CEC in the surface horizons since the considerable CEC contributed by the organic matter component is strongly pH-dependent.

All of the soil series of the area that are in this subcategory as shown below are in the Black and Dark Gray Chernozemic great groups.

Black Chernozemic Soils

Fergy (FRY)

Jeffrey (JFF)

La Fond (LFN)

Ponoka (POK)

Vilna (VIL)

Dark Gray Chernozemic Soils

Egremont (EGO)

Kehiwin (KHW)

Rimbey (RMY)

Winterburn (WTB)

6.4.2.3.3 Soils on relatively recent or slightly altered materials, subcategory 3.3. This subcategory consists of soils with little or no development found on the floodplains and the generally weakly developed soils on the rough broken land along the valleys. These soils are heterogeneous, varying greatly in texture, depth and degree of development. Flooding and new depositions will obliterate from time to time the effects of acidity inputs on soils of the floodplains. Runoff, erosion and exposure of new materials on rough broken land will also minimize or obliterate acidification effects. This subcategory consists of the following two mapping units:

Alluvium (ALL)

Rough Broken Land (RB)

7. GENERATION OF MAP DEPICTING AREAL DISTRIBUTION OF SENSITIVITY SUBCATEGORIES

The reconnaissance soil survey map of the area (Sand River Area 1975) constituted the cartographic basis for preparation of the map depicting the areal distribution of the soils by sensitivity subcategories. It is recommended that in using the sensitivity map, the soil survey map should be consulted regarding the kinds of soils involved in particular areas.

7.1 THE RECONNAISSANCE SOIL SURVEY MAP

Since the soil survey was of a reconnaissance type it is essential to recognize the level of detail with which it was possible to delineate the different kinds of soils. The following statement from Kocaoglu (Sand River Area 1975) in the soil survey report regarding soil survey field operations will indicate the reconnaissance level of detail with which the soils were examined and delineated.

"The soil survey of the Sand River map area was conducted in the field at a reconnaissance level of detail using field maps at a scale of 1:63 360 and aerial photography at a scale of 1:31 680. Soil profiles were systematically studied in test pits and at road cuts at approximately one-half mile intervals along all roads, trails and road allowances suitable for car or truck travel. In inaccessible areas all-terrain vehicles were used to travel seismograph lines and trails and the data recorded were augmented by aerial photo interpretation. At each test pit, soil profile morphology was examined and each horizon described...

Soil and topographic boundaries were plotted on the aerial photographs by correlating the soil features observed with landscape features such as landform and percent slope. These boundaries were than transferred to the field maps. Since soils form a continuum over the landscape the soil boundaries drawn do not always represent abrupt changes from one soil to another. The

majority of the map units shown on the accompanying soil map are complexes of two or more recognized soil series which individually could not be separated by boundaries at the scale of mapping used. Each series is indicated by a letter symbol followed by a number representing the decile proportion of that series within the mapping units. The soil boundaries drawn therefore separate areas within which a recurring sequence of series occurs, and complexes on either side of the boundary may differ in only one of the series recognized..."

The foregoing statement indicates that the soil mapping units shown as delineations on the soil survey map may include soil of only one series or they may include soils of two or three series (or series complexes). The following soil mapping units were selected to serve as examples:

1. Soil mapping unit LCY. The delineations identified by the symbol LCY are comprised of soils that are characterized by the La Corey series (LCY).
2. Soil mapping unit ABC8-GMT2. In delineations identified by this compound symbol, 80% of the soil area is characterized by the Athabasca series (ABC) and 20% by the Grosmont series (GMT).
3. Soil mapping unit LCY5-NTW3-TR2. This compound symbol represents delineations that encompass soils of which 50% are characterized by the La Corey series (LCY), 30% by the Nestow series (NTW), and 20% by the organic soil of the Tucker series complex (TR).
4. Soil mapping unit LCY5-SDN3-RMY2. Of the soils that occupy the delineations identified by this compound symbol, 50% are characterized by the La Corey series (LCY), 30% by the Spedden series, and 20% by the Rimbey series.

7.2 CLASSIFICATION OF SOIL MAPPING UNITS INTO SENSITIVITY SUBCATEGORIES

The classification of soil series and series complexes into sensitivity subcategories served as the basis for a comparable classification of the soil mapping units. Where the soil mapping units included soils of two or three series the procedure followed was to assign to the unit the sensitivity classification of the dominant series or series complex (constituting 50% or more of the mapping unit). This procedure was modified somewhat for some soil mapping units. An example is the soil mapping unit mentioned previously, identified by the symbol LCY5-SDN3-RMY2. The La Corey series (LCY) classified into sensitivity subcategory 2.1, comprised 50% of the mapping unit. The other two series, Spedded (SDN) and Rimbey (RMY), with sensitivity sub-categories 2.2 and 3.2 respectively, constituted the other 50%. A sensitivity subcategory classification of 2.1 for the entire mapping unit would be biased in favour of this subcategory, so in this case a sensitivity subcategory of 2.2 was assigned to this mapping unit. The latter classification represents more or less an average of the three subcategories.

Soil mapping units that are comprised of two or more series carry an inherent bias when the interpretations of the dominant series are extended to apply to the entire unit as was done in this report. This bias is evident in the values obtained for the relative extent of each sensitivity subcategory in the area (Table 8). Two methods were used to determine the relative extent of the subcategories; one by summing the areas of the respective series, and the other by measuring the areas of sensitivity subcategories depicted on the sensitivity map. The data presented in Table 8 show the overwhelming influence of the Orthic Gray Luvisol soils, most of which are classified into the sensitivity subcategory 2.1. This subgroup of soils occupies almost 55% of the land area. Since soils of this subgroup are the most prevalent

Table 8. Relative extent in percent of sensitivity subcategories determined by summing of areas in respective series and in comparable soil mapping units shown on the soil sensitivity map.

Sensitivity Subcategory	Percent of Land Area	
	By areal measurement of soil mapping units	By summing of series
1.1	4.7%	9.2%
1.2	6.2	8.8
	10.9	18.0
2.1	61.9	46.0
2.2	7.5	8.6
2.3	3.0	4.7
	72.4	59.3
3.1	6.2	11.6
3.2	7.8	8.8
3.3	2.7	2.3
	16.7	22.7

they frequently are predominant in the mapping units that include two or more series or series complexes. The discrepancy in relative extent of subcategory 2.1, due to the dominance of Orthic Gray Luvisol soils in soil mapping unit interpretations of sensitivity, emphasizes the need mentioned earlier to consult the soil survey map where soils of a particular locality are of interest.

7.3 PROCEDURE FOR PREPARATION OF SENSITIVITY MAP

It was deemed desirable to develop a map generating procedure that would permit subsequent revisions of the areal distribution of sensitivity categories without having to repeat the entire cartographic operations. Such revisions may be deemed desirable in the future as new or additional data on soils or new developments and information regarding the kind or quantity of acidifying inputs become available. For this reason computer data processing procedures were developed both for recording and storage of the areal distribution of soil mapping units and for generating the soil sensitivity map after sensitivity subcategories had been assigned to the mapping units. These procedures included the following operations.

7.3.1 Digitizing the Entire Soil Survey Map by One Quarter Section (160 acres) Cells

This operation was performed according to the procedure discussed by Wehde et al. (1980); and Schneider and Amanullah (1979). The cellular system was chosen because, as pointed out by Wehde et al., it is simpler in operation and considerably less costly than the polygon system.

In the digitizing operation a systematic coding system was employed whereby the location of each quarter secion was recorded by Range, Township and quadrant of the section. The symbol of the soil mapping unit that covered the quarter section cell was encoded. Where segments of more than one soil mapping

unit appeared in the quarter section cell, the most extensive one, estimated visually, was assigned to that cell. In addition to the soil mapping unit, the class of topography shown on the map was also encoded for each quarter section.

7.3.2 Key Punching and Organization of Encoded Soil Mapping Unit Data

All of the encoded data by quarter section cells was key punched and then, by computer processing, the soil mapping units were segregated and organized into a sequential alphabetical list according to the first letter in the symbol for the dominant series or series complex in the soil mapping unit.

7.3.3 Assignment of Sensitivity Subcategory Classification to Soil Mapping Units

The method for determining the sensitivity classification of the soil mapping unit from the comparable classification of soil series and soil series complexes was discussed previously. The determined sensitivity subcategory designation was added to each mapping unit in the alphabetical list developed in the preceding operation. The assigned sensitivity designation was also added to the encoded data compiled for each quarter section cell to complete the master file for computer-generation of the sensitivity map and for storage for possible revisions in the future or for other purposes.

7.3.4 Computer Generation of the Soil Sensitivity Map of the Area

The stored encoded data for each quarter section cell described above were computer processed to generate the soil sensitivity map on a scale of 1:250 000. The color and pattern of printout symbols for each sensitivity subcategory shown on the printout map were chosen after several combinations of three colours and several symbol patterns were tried. The cost per copy

of the computer-printed map was about $40.00 in 1980. Because of the relatively high cost of map reproduction a limited number of copies of colour transparency slides have been prepared of the map.

8. RECOMMENDATIONS FOR USE OF THE SENSITIVITY CLASSIFICATION OF SOILS

8.1 GENERAL RECOMMENDATIONS

The report presents estimates and discussion of the relative sensitivity of each kind of soil found in the area to effects of acidification. It is anticipated that this information would be most useful if it is considered as a basis or background for planning programs and measures directed to problems that may develop due to increased acidification. The significance of the problems will likely be related to the area of interest. For example, since most of the soils in the area are medium acid to neutral in reaction, a modest input of acidity may result in a marked decrease in soil pH. In slightly acid soils this represents an effect that would be critical in production of some agricultural crops but this effect may be less important in other areas of interest such as forestry, wildlife or recreation. It is recommended therefore that for the most effective use of this information, specialists in agriculture, forestry, wildlife, recreation and industry should be consulted as to how this information can be applied most effectively in their respective areas of interest. It would also be constructive if the needs in the several areas of interest would be identified so that appropriate additional interpretations could be made.

8.2 OTHER RECOMMENDATIONS AND COMMENTS

8.2.1 Use of the Soil Sensitivity Map

Where information concerning the sensitivity of soils of a certain tract is desired it is recommended that the soil survey map in addition to the sensitivity map be consulted. The minimum area shown on the sensitivity map is one quarter section. Where the soil delineations are very small or where the

boundaries of two or more delineations meet on a quarter section the smaller portions will not be recognized in the sensitivity designation for the quarter section. These omitted portions however can be identified on the soil survey map and the sensitivity classification of the component soils can be obtained from the subcategory in which they were included as shown in Table 5 and Appendix B.

8.2.2 The Sensitivity Subcategories

The subcategory contains information on the sensitivity-pertinent properties of the included soils and also includes some discussion of the anticipated behaviour of these soils in response to inputs of acidity. The soil series and series complexes placed in the subcategory are identified so additional information on the particular soils can be obtained from the soil survey report. It is suggested that the subcategory be recognized as the more effective source of information on the sensitivity of soils rather than the broad category.

8.2.3 Siting of Emission Sources

The sensitivity classification of the soils and the map showing the areal distribution by sensitivity subcategories indicate the sensitivity of the soils of areas that are likely to be subject to deposition of airborne emitted materials from local sources. This information on soil sensitivity and comparable information on the other components of the ecosystem of the area would provide an ecological background for siting of the emission sources. Troedsson and Nilsson (1980) studied the sensitivity of soils of the coastal areas of southern Sweden to assess the likely effects on different soils of acidification that would be associated with future sitings of coal-fired power stations in the region.

8.2.4 Planning and Interpreting Soil Sensitivity Investigations

It is recommended that in planning of research directed to investigations of soil sensitivity, the possible influence of the sensitivity-pertinent properties and attributes on the results obtained should be recognized. A similar recommendation is made regarding interpretation of data already available. The latter recommendation may be particularly pertinent to use of information from other regions. Considerable data have been generated in eastern North America and in northwestern Europe. In numerous cases the research involved very acid, coarse-textured soils of areas subject to considerable rainfall. The direct applicability of their findings to Alberta's less acid soils and lower rainfall should be considered with appropriate caution.

8.2.5 Short and Long Term Effects

The more noticeable change in soil pH that is associated with a relatively modest change in base saturation of medium acid to neutral soils could be considered as a short term effect. By comparison the loss of an appreciable proportion of exchangeable bases in the above soils would reflect more of a long term effect. Likewise the conversion of these soils to soils that are very strongly acid represents a considerable change that could be viewed as a long term effect. The converted data regarding gross BFC of soils by soil depth intervals presented in Tables 6 and 7 and the pH-base saturation relationship depicted in Figure 3 provide an approach that could be used for predicting the possible short term changes in soils of the area, in response to given surficial inputs of acidity. To facilitate estimation of the response, the added acidity will need to be expressed in comparable units, such as in E/m^2.

8.2.6 Influence of the Reaction (pH) of Acidity Inputs

One of the factors that influences the magnitude of response of soils to inputs of acidity is the difference between

the pH of soils and that of the added acidity. Bache (1980a) indicated that the larger the difference the more sensitive is the soil. On the other hand, if the pH of the soil and that of the added acidity are similar, little if any change in soil pH can be expected. This soil pH-acidity pH relationship may explain the relatively large decrease in soil pH (0.5 to 1.0 unit) reported by Laverty and Carson (1977). In this case, neutral to mildly alkaline soils were exposed for 16 years to downwind deposition from two emission sources.

8.2.7 Soil Survey Soil Sensitivity Classification

Over the last several decades the information and data generated by soil surveys have been used to interpret and classify the soils surveyed for an increasing number of purposes as shown in the Sand River soil survey report. The impact of acidifying materials from anthropogenic sources can be expected to become progressively more extensive with expanding industrial activity and fertilizer use. In view of this progressive expansion it is recommended that interpretation and classification of soils regarding their sensitivity to acidification be considered as one of the customary objectives of soil surveys.

Soil surveys provide a data base that can be used to classify soils according to their sensitivity to effects of inputs of acidity and also to show their areal distribution by sensitivity categories. It is likely however that the effectiveness of the data base could be increased or refined by some pertinent research or additional specific data as needed in each soil survey area. As an example, in forested soils the forest floor markedly influences their sensitivity to effects of air borne acidity (Voigt 1980). Thus in areas where forested soils are common the data base should include ample pertinent data on the forest floor characteristics.

9. CONCLUSIONS

The field information and laboratory-derived data that were acquired on soils of the area during the soil survey provided an effective data base for evaluating those soil properties and attributes that were considered to be sensitivity-pertinent.

The BFC of soils as estimated from their determined CEC values served as the criterion for classifying the soils into the three broad categories of relative sensitivity to acidification. Because of its significance the BFC of selected soils should be determined by appropriate laboratory techniques to provide a reference base to which the estimated BFC could be compared.

Analysis of the data available indicate that CEC provides an effective index of the BFC of soils that are medium acid to neutral in reaction. Most of the soils of the Sand River area are in this reaction range. The analysis of data suggests that CEC is less effective as an index of BFC of soils that are very strongly acid.

The procedure developed for the preparation of computer-generated maps to depict the areal distribution of soils according to their sensitivity is advantageous in that the maps can be revised readily as deemed desirable. The main disadvantage is that reproductions of additional copies of the map are costly.

It is felt that the criteria and scheme employed for the sensitivity classification of soils of the Sand River area could be applied in other areas in Alberta where the soils are medium acid to neutral in reaction. New appropriate subcategories could be added as needed.

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11. APPENDIX

11.1 UNITS FOR EXPRESSING SOIL PARAMETERS ON AREA AND AREA-VOLUME

Additions of materials to the land surface are generally expressed in weight or chemical equivalent units over an area - e.g., Kg S/ha or keq NH_4/ha. Quantities of materials dissolved in rainfall may be expressed in ppm or in mg/L. Within the soil the magnitudes of the constituents are usually given on a weight basis as percent or ppm of a soil or as chemical equivalents for a given weight of soil - e.g., meq/100 g.

Since additions of materials on to the soil surface are areal in distribution, the soil parameters indicative of the capacity of the soil to react with these additions should not only be expressed on a similar basis but should also include a depth dimension of the soil affected. Thus units expressing the gross reactive capacity of the soil should actually be expressed on area-volume basis.

Several Scandinavian workers have used the gram equivalent (1000 meq), designated by the symbol E, as a quantity unit for such chemical constituents as exchangeable bases or acidity in a square metre of soil to a given depth. It is a convenient unit for soil chemical quantities of this magnitude since the numerical expressions are generally small whole numbers.

The approach followed in this report was to express the inputs and the parameters of the soil body affected on an area or area-volume basis. The quantity unit E was adopted to express quantities of chemical constituents or values of pertinent soil properties. Thus acidity inputs, quantities of exchangeable bases and values for CEC are expressed, where applicable, in E units per square metre (E/m^2).

The magnitudes of exchangeable bases and CEC of the various soils were expressed in E/m^2 in the tabular compilation by the following soil depth intervals: 0 to 5 cm, 5 to 18 cm,

18 to 50 cm, and in some cases 50 to 100 cm as exemplified by Table 6. It was postulated that the organization of data on CEC and exchangeable bases would serve as an index of the depth distribution of the gross BFC or exchangeable base content of the various soils. The 0 to 5 cm was chosen to represent the surficial soil and hence would receive most of the impact of surficial inputs from airborne sources. This layer and the 5 to 18 cm depth interval combined were considered to be comparable to the plow layer while the 18 to 50 cm depth would characterize the subsoil. The 50 to 100 cm was included for the more permeable soils and for organic soils because of their low bulk density.

All of the data on CEC and exchangeable bases for soils of the area were originally reported on a weight basis by horizons. To convert these data to area-volume basis by depth intervals necessitated recalculation of soil quantities according to the thickness and bulk density of each horizon to depths of 50 or 100 cm. The main problem encountered was deriving bulk density values by horizons. For mineral soils various sources such as technical articles, reports and thesis on soils of the province that included bulk density measurements were reviewed. The information provided by these sources served as the basis for estimation of the bulk density values employed in the recalculations. The data reported by Boelter (1969, 1974) and Walmsley (1977) were consulted in choice of bulk density values for organic soils.

Estimated bulk density values by horizons:

Soils	Horizon	Bulk Density
Chernozemic	Ah	1.1
(Loamy and	Ap	1.2
fine loamy)	B	1.5
Luvisolic	Ah	1.1
(Loamy and	Ae	1.3
fine loamy)	AB	1.4
	Bt	1.5
Brunisolic	Ae	1.4
(sandy)	Bm	1.45

Soils	Horizon	Bulk Density
Gleysolic (Loamy, fine loamy, and fine clayey)	Ah	1.1
	Ae	1.3
	B (loamy)	1.5
	B (clayey)	1.4
Organic	Of	0.1
	Om	0.2
	Oh	0.3

11.2 ALPHABETIC LIST OF SOIL SERIES, SERIES COMPLEXES AND LAND TYPES AND SYMBOLS AND SENSITIVITY CLASSIFICATION OF EACH

Symbol	Soil or Land Type	Sensitivity Subcategory
ALL	Alluvium	3.3
AMK	Amisk	1.1
ABC	Athabasca	2.1
BLY	Belloy	1.2
BL	Birkland	2.3
BN	Bonnie	3.1
CT	Chatwin	3.1
CUN	Clouston	1.1
COA	Codesa	1.2
COD	Codner	3.1
DKN	Daken	3.1
EDW	Edwand	1.1
EGO	Egremont	3.2
FWT	Fawcett	2.2
FRY	Fergy	3.2
GBL	Gabriel	1.2
GOY	Glory	2.1
GOG	Good Ridge	2.1
GDI	Grandin	2.1
GMT	Grosmont	2.2
HD	Hilda	3.1
JVI	Jarvie	3.1
JFF	Jeffrey	3.2
KHW	Kehiwin	3.2
LCY	La Corey	2.1
LFN	La Fond	3.2
LVT	Lavesta	2.1
LIZ	Liza	1.1

Symbol	Soil or Land Type	Sensitivity Subcategory
ML	Maloy	3.1
MN	Manatokan	3.1
MPV	Mapova	3.1
MYW	Maywood	2.1
NTW	Nestow	1.1
NWO	Newbrook	3.1
NIT	Nicot	1.1
POK	Ponoka	3.2
RB	Rough broken land	3.3
RDW	Redwater	2.1
RMY	Rimbey	3.2
SDN	Spedden	2.2
SB	Stebbing	2.3
SL	St. Lina	3.1
TWI	Tawatinaw	1.2
TOM	Tolman	2.1
TM	Tompkins	2.3
TMN	Tomson	1.2
TR	Tucker	2.3
VIL	Vilna	3.2
WST	Winston	2.2
WTB	Winterburn	3.2

11.3 SUMMARY OF SOIL TEST pH DATA FOR SAND RIVER AREA

The Soil and Feed Testing Laboratory of the Alberta Agriculture Soils Branch performs soil tests on soil samples submitted by farmers and others throughout the province. One of the tests conducted on these soil samples is the determination of soil pH. During the period 1961-1979 pH was determined on 6 199 samples submitted from the Sand River area, originating almost entirely in the farming area shown in the soil survey report (Sand River Area 1975).

In response to our request, Mr. J.A. Carson summarized the soil test pH data available for the Sand River area and reported them as a mean value for each of the sections in which the samples were taken during the 1961-1979 period. These mean pH values were derived for 1 184 sections located in 100 townships. The number of samples originating by sections varied widely, ranging from 1 to 65 per section.

Most of the samples submitted were either neutral or slightly acid in reaction. The distribution of the section mean values by acidity classes is shown below as percent of the total of 1 184 sections represented.

Acidity Class pH Range	%
Less than pH 5.6	0.4
pH 5.6 to 6.0	2.5
pH 6.1 to 6.5	32.9
pH 6.6 to 7.3	55.3
above pH 7.3	8.9

11.4 GLOSSARY OF TERMS

active acidity - The activity of hydrogen ion in the aqueous phase of a soil. It is measured and expressed as a pH value.

alluvium - Material such as clay, silt, sand, and gravel deposited by modern rivers and streams.

bulk density, soil - The mass of dry soil per unit bulk volume. The bulk volume is determined before the soil is dried to constant weight at 105°C. It has been called apparent density.

cation exchange capacity - The total amount of exchangeable cations that a soil can adsorb. It is sometimes called "total exchange capacity", "base exchange capacity", or "cation adsorption capacity". It is expressed in milliequivalent per 100 g of soil or of other adsorbing materials such as clay.

clay - (i) As a particle-size term: a size fraction less than 0.002 mm in equivalent diameter. (ii) A soil-textural class.

clay mineral - Finely crystalline hydrous aluminum silicates and hydrous magnesium silicates with a phyllosilicate structure.

coarse texture - The texture exhibited by sands, loamy sands, and sandy loams except very fine sandy loam. A soil containing large quantities of these textural classes.

denitrification - The gaseous loss of nitrogen by either biological or chemical mechanisms, but exclusive of ammonia volatilization.

forest floor - All dead vegetable and organic matter, including litter and unincorporated humus, on the mineral soil surface under forest vegetation.

fulvic acids - A term with various meanings that usually refers to the mixture of organic substances that remains in solution when a dilute alkali extract from the soil has been acidified.

horizon, soil - A layer of soil or soil material approximately parallel to the land surface; it differs from adjacent genetically related layers in properties such as color, structure, texture, consistence, and chemical, biological, and mineralogical composition.

humic acids - A mixture of various dark-coloured organic substances precipitated by acidifying a dilute alkali extract from the soil. The term is used by some workers to designate only the alcohol-insoluble part of this precipitate.

humus - (i) The fraction of the soil organic matter that remains after most of the added plant and animal residues have decomposed. It is usually dark coloured. (ii) Humus is also used in a broader sense to designate the humus forms referred to as forest humus. They include principally mor, moder, and mull.

landscape - All the natural features such as fields, hills, forests, and water that distinguish one part of the earth's surface from another part. Usually it is the portion of land or territory that the eye can see in a single view, including all its natural characteristics.

mineral soil - A soil consisting predominantly of, and having its properties determined predominantly by, mineral matter. It contains less than 17% organic carbon except for an organic surface layer that may be up to 40 cm (16 inches) thick if formed of mixed peat (bulk density 0.1 or more) or 60 cm (24 inches) if of fibric moss peat (bulk density less than 0.1).

minerotrophic - Wetland sites that receive terrestrial mineral nutrition in addition to precipitation by flowing or percolating groundwater which has earlier been in contact with mineral soil.

nitrification - The biochemical oxidation of ammonium to nitrate.

organic matter, soil - The organic fraction of the soil; includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. It is usually determined on soils that have been sieved through a 2.0 mm sieve.

particle-size distribution - The amounts of the various soil separates in a soil sample, usually expressed as weight percentages.

peat - Unconsolidated soil material consisting largely of undecomposed, or only slightly decomposed organic matter.

profile, soil - A vertical section of the soil through all its horizons and extending into the parent material.

reaction, soil - The degree of acidity or alkalinity of a soil, usually expressed as a pH value. Descriptive terms commonly associated with certain ranges in pH are: extremely acid, less than 4.5; very strongly acid, 4.6 to 5.0; strongly acid, 5.1 to 5.5; medium acid, 5.6 to 6.0; slightly acid, 6.1 to 6.5; neutral, 6.6 to 7.3; slightly alkaline, 7.4 to 7.8; moderately alkaline, 7.9 to 8.4; strongly alkaline, 8.5 to 9.0; and very strongly alkaline, greater than 9.0.

rough broken land - An area having steep slopes and many intermittent drainage channels, but usually covered with vegetation.

sand - (i) A soil particle between 0.05 and 2.0 mm in diameter. (ii) Any one of five soil separates: very coarse sand, coarse sand, medium sand, fine sand, or very fine sand.

sandy - Containing a large amount of sand. It may be applied to any one of the soil classes that contains a large percentage of sand.

silt - (i) A soil separate consisting of particles between 0.05 and 0.002 mm in equivalent diameter. (ii) A soil textural class.

survey, soil - The systematic examination, description, classification, and mapping of soils in an area. Soil surveys are classified according to the kind and intensity of the field examination.

texture, soil - The relative proportions of the various soil separates (sand, silt, clay) in a soil, usually identified by a texture class such as loamy sand, sandy loam, loam, silty clay loam, clay, etc.

water holding capacity - The moisture content of the soil after it has drained for two or three days following saturation.

11.4.1 Explanation of Chemical Units

E equals one gram equivalent as defined in chemistry. It is the weight of substances in grams that have a reacting or combining power equivalent to 1 gram atomic weight of hydrogen.

keq = kiloequivalent = 1000E

meq = milliequivalent = one-thousandth of E

The E values in grams for the elements referred to in the report are:

Element	Equivalent Weight in Grams
Ca	20
K	39
Mg	12
Na	23
N (as NH_4 or NO_3)	14
S (as SO_4)	16